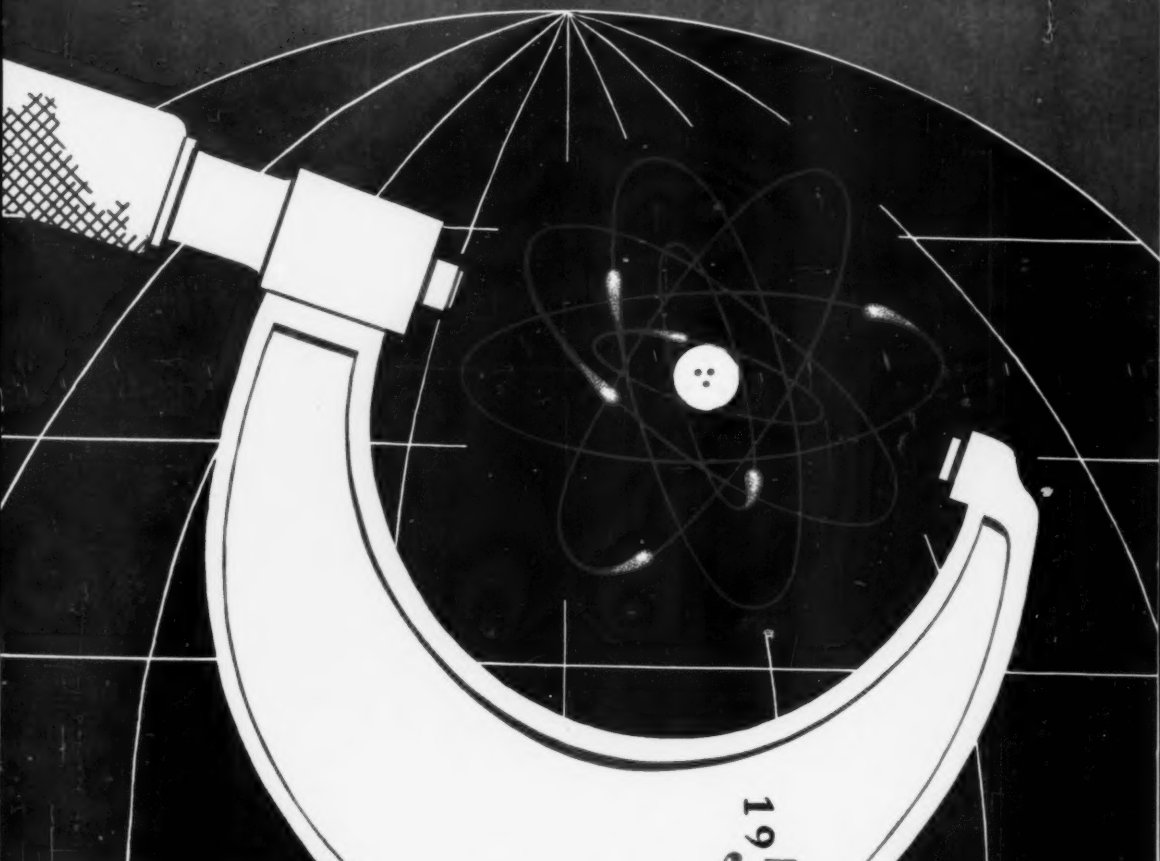
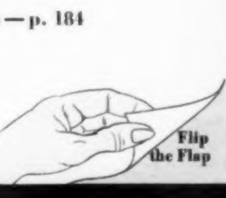
METAL PROGRESS



january

IN THIS ISSUE



As I was saying—

THE A.S.M. has always been and always will be an educational Society, and evidence of that fact is shown in every activity in which the Society is engaged. It may be an exposition, with its multitudinous educational features, or the publication of *Metal Progress* or "Metals Handbook" or *Metals Review* or *Transactions* or the many technical books and other services, all combined to place the at the forefront of educational agencies.

Just as an indication of the tremendous production of the Society in the educational field, one need but point out that in 1949 (the year in which the survey was made) the Society collected, edited, published, and distributed over 100 million pages of engineering information on the subject of metals.

I like to pause and think about the tremendous service and impact of that amount of engineering information (and you well know that the material published by the Society is real engineering information from beginning to end) and consequently there is no raising of the eyebrows or even questioning the fact that the American Society for Metals is really "The Engineering Society of the Metals Industry".

Among the national committees working in the interest of the Society's educational program are the three devoting their activities to pointing out how the may assist colleges, high schools, and vocational schools and Chapters in their educational work.

These three national committees and their functions are as follows:

The Advisory Committee on Metallurgical Education devotes itself entirely to educational problems at the college level. Some of its functions are *(a)* to encourage graduates of private schools and high schools to enroll in engineering colleges with the ultimate purpose of specializing in metallurgy; *(b)* to assist and encourage the college undergraduate in his work and to furnish him such aid as the Society may possess which will help him in his school work; *(c)* to inaugurate a plan for summer employment of the undergraduate engineering students in industry; *(d)* to prepare suitable texts for process metallurgy, and *(e)* to study and review the desirability of scholarships and other financial aids to and for metallurgical students.

Another committee known as the Educational Committee has for its purposes the selection and formation of the educational lecture series presented at the annual convention. In addition, it selects and supervises the production of moving pictures on metallurgical subjects and produces and distributes metallurgical teaching aids. It also serves as advisor at the Chapter level for educational courses.

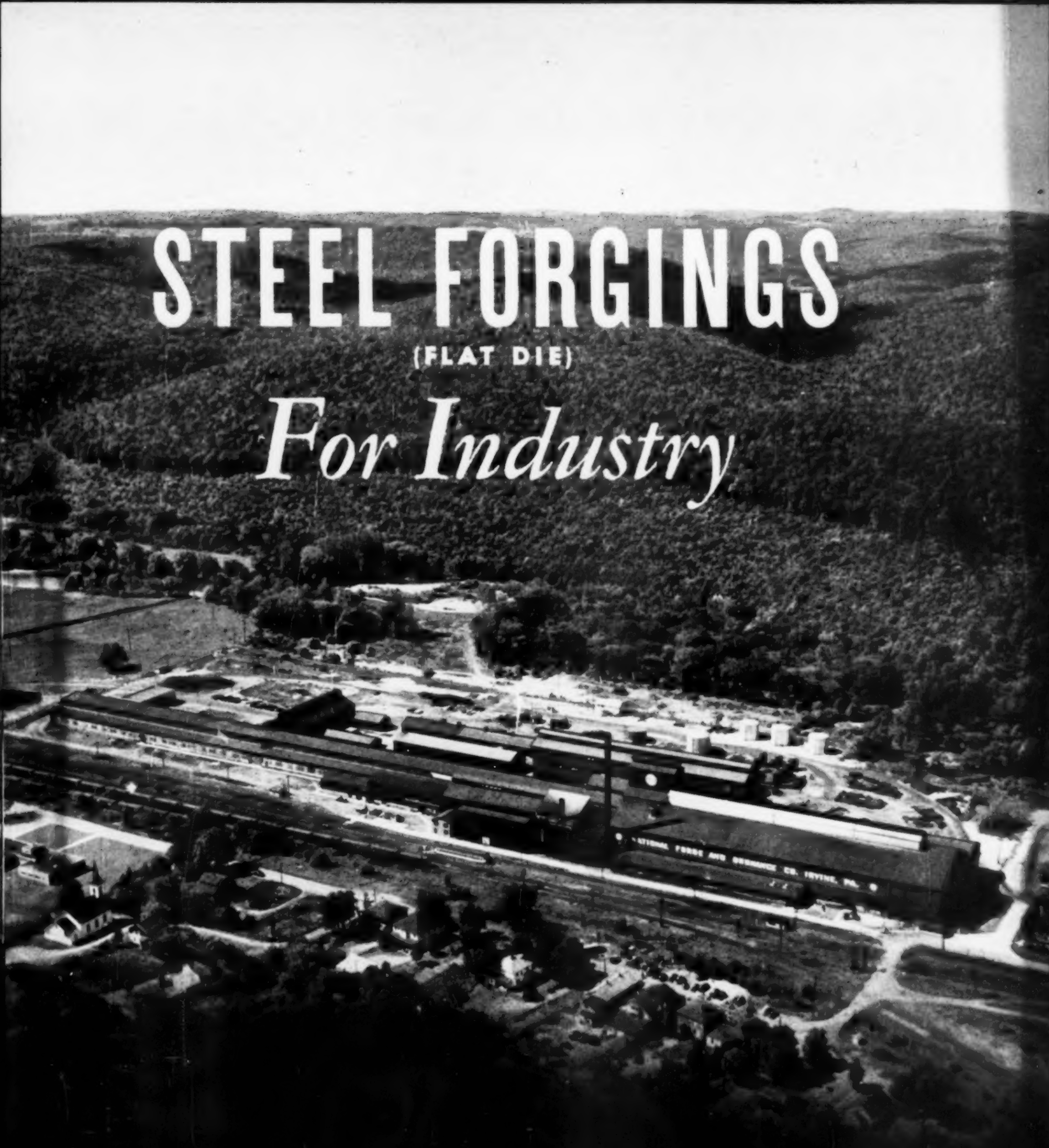
A committee devoted to educational activities at the vocational and trade school level has just been appointed by President Chipman. It will be advisory to the Board of Trustees and will recommend and indicate the ways and means by which the Society may be of assistance to those vocational and technical schools teaching metal technology. It is hoped that in this way the Society may be able to assist in the training of laboratory technicians so they will develop into worth-while assistants in the laboratories and metallurgical departments of industry and help to alleviate in a way the scarcity of the metallurgical engineers.

There are many other ways in which the Society lends its weight to assist in the educational work to be accomplished. Not the least of these are the educational lecture courses presented by the Chapters, some series having an enrollment of over 500. Thus the Chapters and the Society demonstrate time and again their value to industry and to the advancement and the progress of the profession.

Cordially yours,

Bill

WM. H. EISENMAN, *Secretary*
American Society for Metals



NATIONAL FORGE AND ORDNANCE COMPANY

IRVINE, WARREN COUNTY, PENNSYLVANIA

Metal Progress is published and copyrighted, 1952, by American Society for Metals, 7301 Euclid Avenue, Cleveland, Ohio. Issued monthly; subscriptions $7.50 a year. Entered as second-class matter Feb. 7, 1921, at the post office at Cleveland, Ohio, under the act of March 3, 1879.

Progress IN NUT TAPPING!

NEW SIZES...NEW HIGH SPEEDS...NEW VERSATILITY

NEW SIZES & SPEEDS—You can now tap a complete range of hex and square nuts, from 10-32 up through 1 1/2" National Coarse, at 75 cutting feet per minute!

NEW VERSATILITY—Convert from right to left hand threads (and vice-versa) in only 90 minutes. Longer tap life and better threads result from National's non-reversing, free-floating, 180-degree hook tap. Clean, chip-free nuts are ideal for power wrenching.

NEW DESIGN—New mechanical features, including electrical safety shutoffs, make this entirely automatic tapper trouble-free.

TAP & TOOL CHANGES—Always quick and easy, spell high output and round-the-clock dependability.

TESTIMONIALS—"Our new 1/4" National ent into the line today and tapped 42,300 1/4 x 20 nuts in eight hours."

"Only four men operate our 60 Precision Tappers, all Nationals."

"Our new 3/4" National tapped 12,300 3/4 x 20 nuts in eight hours."

"We average 85,000 to 100,000 cold-formed nuts per tap."

"For tapping touchy stainless locknuts for jet aircraft engines, we use Nationals exclusively."

"Our six Precision Tappers—four 1/4" and two 3/8"—have operated 40 hours per week for 12 months, averaging 6,000 gross of cold-formed nuts per week. Tap consumption averaged less than half a tap per machine per week."

"We beat all previous records by tapping 952,000 nuts in one 24-hour day recently on our Nationals."

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in trained hands
. . . there's more than meets the eye in Alloy Rods arc welding electrodes
NO WELDING ROD is better than the skill of the welder using it . . . but any skilled welder can get consistent quality welds, faster and cheaper, using Alloy Rods' seven complete lines.
Principal reasons: Alloy Rods' continuous quality control—continually producing identical characteristics in each grade of electrode from every production run . . . continuous on-the-line testing and inspection . . . the continuous efficiency and exclusive production techniques of the world's most modern electrode manufacturing plant, producing arc welding electrodes only.
Although our Distributors may temporarily be out of stock on certain types, we urge you to keep in touch with them on your requirements. After all, quality is always worth waiting for.
NAMES TO REMEMBER IN ARC WELDING
ARCALOY for stainless steel
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Brass
Valves
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The free cutting characteristics of Brass are ideal in the manufacturing of all types of valves and other castings that require machining.
This outstanding quality of a Brass Casting . . . . . . MACHINABILITY . . . makes it an efficient and economical friend of the machinist.
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Tool Steel Topics

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation. Export Distributor: Bethlehem Steel Export Corporation

Our Tool Steel Engineer Says:

Double-Tempering adds service life to high-alloy tool steels

It's always best to double-temper tools made from the high-alloy tool steels such as the high-speed and hot-work types. These steels retain more austenite than tool steels with low-alloy content.

The first tempering relieves stresses in the martensite formed in the quench . . . and conditions the retained austenite so that it transforms to martensite during cooling from the tempering temperature. A second tempering relieves stresses due to the newly formed martensite.

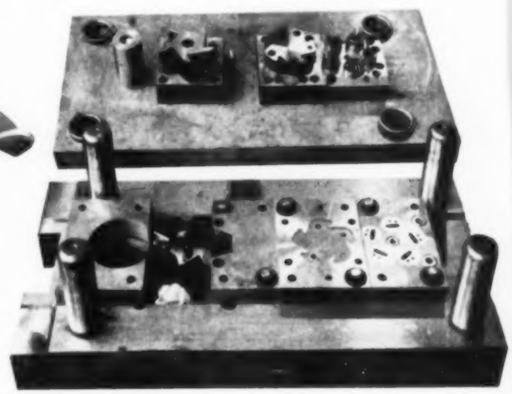
Omitting a second temper on hot-work steels may lead to early failure by heat-checking. And with high-speed steels and high-carbon, high-chromium steels, such omission may result in abnormal sensitivity to grinding checks.

Lehigh H Trims Costs on Lawn-Mower Heads

Giving your lawn that well-groomed look depends a lot on the precision of your trusty mower. The "head", for example, is a pretty important part of a lawn mower because it keeps those whirling blades in proper alignment.

These heads are produced by one large manufacturer on a progressive die of our Lehigh H tool steel which blanks, punches, and forms them from 3/16-in. steel strip. Hardened to Rockwell C-60, this die is mounted in a 200-ton press and turns out about 2000 pieces in an 8-hour shift. Costs are kept low by the long-wearing properties of this high-carbon, high-chromium tool steel.

Lehigh H is a good choice for this operation because it has the maximum wear-resistance necessary for long-run jobs involving severe service. And because it's air-hardening, it keeps distortion to a minimum during heat-treatment.



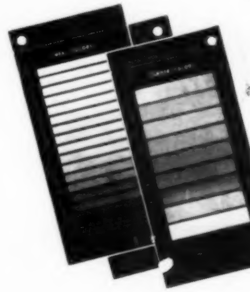
Lawn-mower heads, one of which is shown above, are blanked, punched, and formed on this high-production progressive die made from Lehigh H.

Scissors by the Million with Swaging Dies of 67 Chisel

A leading scissors-maker is an enthusiastic user of our 67 Chisel tool steel. He makes a variety of scissors, but specializes in the blunt-end kind that young folks use for paper dolls and such.

One of the cold-swaging dies of 67 Chisel has produced about 1,100,000 pieces. They have redressed the die five times since it was placed in service, each time removing about .003 in. And the shop reports that the die is good for plenty more.

Here's a case that illustrates the satisfactory wear-resistance that can be obtained with a steel that's basically a shock-resisting type. 67 Chisel, in fact, is quite versatile. It's fine with all sorts of tools that have to withstand heavy impacts. And when carburized for extra-long-wearing service, this chrome-tungsten grade is first choice for master hobs used in cold-hobbing mold cavities.



WRITE FOR THIS HANDY CHART OF HEAT AND TEMPER COLORS

Thousands of steel users and treaters depend on this convenient color guide to estimate the temperatures of heated steels. Printed in full, natural tones, the heat colors are on one side and temper colors on the other side. The lemon, orange, brown, blue and other colors that indicate the temperatures of heated steel are accurately reproduced. Both Fahrenheit and Centigrade figures are given for each color.

If you'd like to have one, write our Publications Department, Room 1041, Bethlehem, Pa. Ask for the Heat and Temper Color Chart.

Bethlehem ULTRASONIC TESTED **Tool Steel**

FULL BORON EFFICIENCY with Grainal Alloys

Grainal is a more reliable means of making boron steels because the titanium, aluminum, zirconium and manganese in the alloy perform an important part of the treatment.

Grainal treatment is able to compensate for variations in oxygen and nitrogen contents of steel and for differences in finishing practice, thus effecting the proper treatment of steels by means of boron-containing alloys and providing constant benefit to properties.

Uniform results are obtained from one shop to another without the necessity of using identical steelmaking practices.

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MAKERS OF ALLOYS VANCORAM CHEMICALS AND METALS


Valuable information for YOU...
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No. 54
Issued by Handy & Harman
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Tells you how to use the Easy-Flo and Sil-Fos Preplacement Formula to get any brazing production you need!
Preplacement of formed shapes of EASY-FLO and SIL-FOS low-temperature silver brazing alloys can give you startling production increases and big savings in metal joining time and costs. Now, the full story is available in this fact-packed new bulletin, complete with case histories and details on how to make the preplacement formula work for you.
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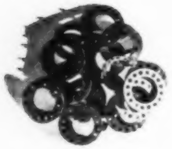
fine Jessop steel is most carefully watched
There is more than skillful melting and working and treating behind Jessop's reputation for the finest specialty steels. Each batch is subjected to rigid quality control at all stages, to assure precise formula and condition. When you buy from Jessop, you buy more than good steel. You acquire metal that is custom-made to your specific need.
HIGH SPEED STEELS • HIGH SPEED BITS • PRECISION GROUND FLAT STOCK • HIGH SPEED AND ALLOY SAW STEELS • HOT WORK DIE STEELS • COLD WORK DIE STEELS • CARBON AND ALLOY STEELS • STAINLESS AND HEAT RESISTING STEELS • VALVE STEELS • STAINLESS-CLAD STEELS • CAST-TO-SHAPE STEELS • COMPOSITE TOOL STEELS • ARMOR PLATE
JESSOP
STEEL COMPANY · WASHINGTON, PENNSYLVANIA

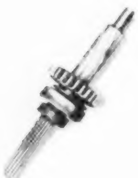
There's a Du Pont Molten Salt Bath for Any Type of Case Hardening

PLAIN CYANIDE for light cases



FOR CASE DEPTHS to 0.010". At temperatures of 1400° to 1600°F. Du Pont cyanide baths supply nitrogen as well as carbon to the steel surface being treated. Distortion is held to a minimum. Wear resistance is greatly increased by the presence of nitrogen. Nitrogen pickup can be controlled by adjusting the temperature of the bath. Du Pont replenishing salts of varying cyanide concentrations permit efficient and economical maintenance of the bath under various operating conditions.

ACCELERATED SALT WS* for medium cases



FOR CASE DEPTHS to 0.040". Du Pont Accelerated Salt WS* has excellent carburizing activity from 1500° to 1650°F. Graphite cover reduces heat radiation and fuming . . . lowers decomposition rate. High fluidity of bath—with resulting reduction in salt "drag-out" on treated stock—and high cyanide concentration eliminate bail-out under normal working conditions. Both salts composing the bath and decomposition products are *completely water soluble for free, easy washing.*

*WATER SOLUBLE

CARBURIZING SALT for deep cases

FOR CASE DEPTHS in excess of 0.025". Predominantly carbon cases are quickly and economically obtained with Du Pont Carburizing Salt at 1650° to 1750°F. Graphite cover, plus low cyanide concentration, holds cyanide decomposition to a minimum—even at relatively high operating temperatures. High-temperature operation permits rapid case penetration and reduces the time required for the carburizing cycle. Case depth is controlled and uniformity assured because of fast and uniform heating.

. . . .

EACH OF THESE BATHS is designed to efficiently produce cases of the desired depth in the shortest possible time at the lowest possible cost. Each is basically simple in operation and is adaptable to mass-production techniques. They're just three of the many Du Pont heat-treating products that can mean top production and maximum economy for your plant.

TECHNICAL ASSISTANCE and advice in the selection of Du Pont heat-treating materials can be obtained by writing or calling our nearest district office. E. I. du Pont de Nemours & Co. (Inc.), Electrochemicals Department, Wilmington 98, Delaware.

DISTRICT OFFICES:

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DU PONT

CYANIDES AND SALTS FOR STEEL TREATING

DU PONT

REG. U. S. PAT. OFF.

BETTER THINGS FOR BETTER LIVING . . . THROUGH CHEMISTRY

May be used with resistance or high-frequency combustion furnaces

Equipped with Unique
THROWAWAY
Cartridge-Type
ABSORPTION TUBES

New, pre-packed, absorption tubes are easily and quickly inserted in Burrell Carbotrane. When spent they are thrown away!

All contacts are leak-proof. The cartridge-type absorption tubes may be stored indefinitely without contamination or deterioration of reagents.

You who are the chemists and technicians of metallurgy, have long expressed desire for a carbon train built into a single piece of laboratory equipment.

Answering this desire, the Burrell Carbotrane is ready to take its place in your laboratory for improved gravimetric determinations of carbons-by-combustion.

The Carbotrane matches, in efficiency, the modern furnaces and analytical balances used. It supersedes the usual assemblies of various parts. Analyses are easier and surer and cost per determination is lower. Built-in timers, with a range up to five minutes, time the periods of combustion.

Because the Carbotrane is leak-proof and contamination-free, errors from these causes are eliminated. It is sturdy and will not tip over.

Two Carbotrane models are available:

Model 120—A double train for use with two-tube furnace. Complete with two sets of absorption tubes $165.00

Model 110—A single train for use with one-tube furnace. Complete with set of absorption tubes $110.00

Prices listed are f.o.b. Pittsburgh, Pa. Order today or ask for Bulletin No. 323 for more detailed information.

*Trademark-Patent Pending

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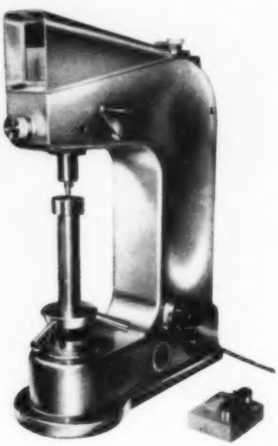
MANUFACTURERS AND DISTRIBUTORS OF SCIENTIFIC APPARATUS AND LABORATORY CHEMICALS

Engineering Digest
OF NEW PRODUCTS

OPTICAL HARDNESS TESTER: Introduced in the United States for the first time is the Officine Galileo universal hardness tester. Especially designed for Rockwell and Brinell hardness tests, the instrument can be adapted to special tests and Vickers measurements. The Galileo tester gives hardness measurements following the Rockwell method on any type metal in the Rockwell A through F Scales by direct reading. Operation of the tester is extremely simple and readings are easily taken. The tester



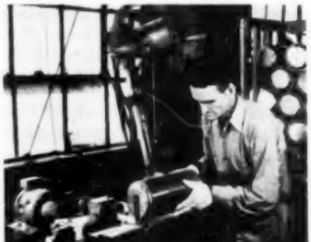
makes use of a lever arm supported on knife edges and projects a magnified image of the hardness reading on a screen. This "optical balance" maintains its calibration over extended time intervals. Loads are interchanged automatically by a patented device which is controlled by an external knob. All loads are obtained by weights which insure absolute constancy of calibration.

For further information circle No. 1 on literature request card on p. 32B

CUTTING OIL SYSTEM: The Gulf Oil Corp. has announced a new technique of lubricating single point cutting tools that is said to increase the life of high speed tools 6 to 12 times and of carbide tools 3 to 5 times while producing an improved surface finish. This technique is based on two developments, the Hi-Jet method of applying lubricant to the tool, and Hi-Jet oil. The method utilizes a nozzle with a fine orifice to direct the oil from *below* the tool. The oil, delivered at a pressure of 400 psi., passes between work and side relief face of the tool and is aimed at the line of contact between work and tool. Part of the oil is forced past the cutting edge and is caught between chip and tool. Two to three times greater cooling is obtained with this method using one-twentieth the oil circulation than for the conventional overhead method. The entire unit consists of a jet, or series of jets, a small pumping unit filter, pressure regulating valve and smoke-quenching attachments to absorb the smoke that develops from contact of oil with tool.

For further information circle No. 2 on literature request card on p. 32B

SOLDERING AND BRAZING: A new type soldering and brazing unit has been developed by the Metallizing Co. of America. The unit is suited to special soldering jobs as well as production runs. It is built to deposit lead and tin-base solders, and also silver and other brazing wires, in liquid or semi-liquid form to a part moving at constant speed under the gun nozzle. Soldering or brazing can be either intermittent or continuous at any desired rate of speed up to 200 lineal ft. of seam per min. Soldering material, in wire form, is fed into the center of a conical flame where it is melted into a liquid or



semi-liquid state, depending upon requirements, and then deposited into the seam or area being soldered or brazed.

For further information circle No. 3 on literature request card on p. 32B

HEAT TREATING FURNACE: The Waltz Furnace Co. has recently announced availability of a new, improved heat treating unit for small tools. Its temperature range is broad enough to permit the heat treatment of all high speed steels, even the

cobalt type. The unit includes preheat furnace, tempering furnace, atmosphere generator, and two quench tanks (one for oil and one for water). The tempering furnace is of the recirculating air type for close temperature control in the lower ranges.

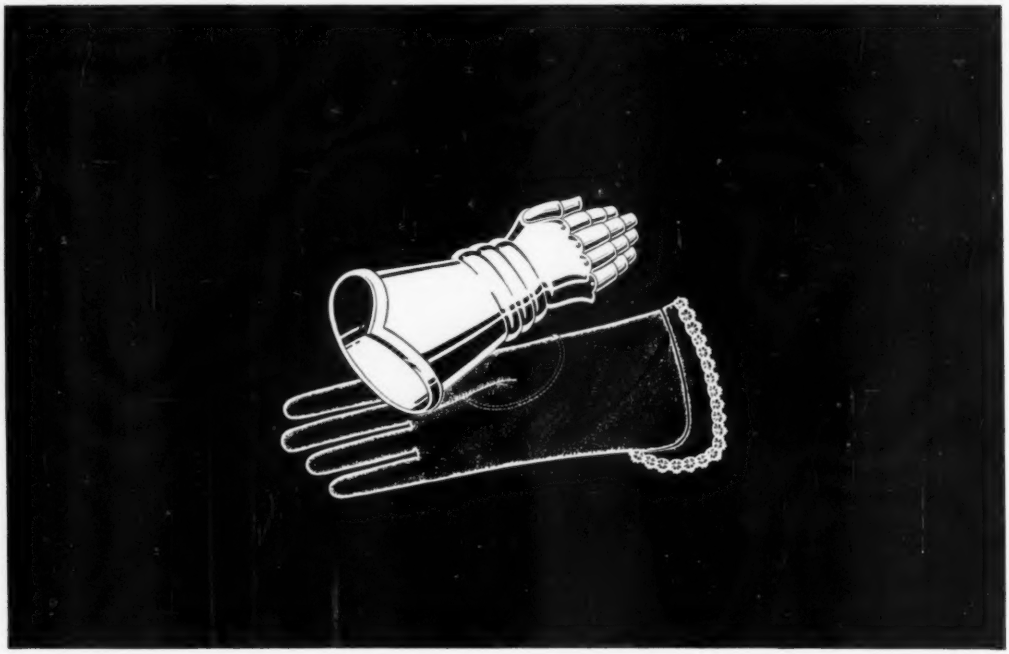
For further information circle No. 4 on literature request card on p. 32B

ALL-PURPOSE CLEANER: Following extensive field tests, the Magnus Chemical Co. announces a new cleaner for all kinds of metal parts, Magnus 751. It is safe for all metals, not attacking, pitting or marring aluminum alloys, bearing metals, cadmium, solder, die cast or any other soft metal. It is non-inflammable. A noteworthy characteristic is the long life of the cleaning solution. Magnus 751 can be used in either hot or cold solution and is followed by a simple cold water rinse after the cleaning period. It closely follows Navy Aeronautical Specification C-86 and Army-Navy Aeronautical Specification AN-C-163.

For further information circle No. 5 on literature request card on p. 32B

BLOWER: A line of blowers in increased capacities is offered by Bill-myre Blower Div., Lamson Corp. Three styles are offered: Model SG (multi-stage) and SM (single-stage), operating at 3500 rpm.; and Model ST operating at 1750 rpm. Outlet pipe sizes are 4 to 24 in. Outlets can be oriented in any of 14 positions, determined by discharge angle and offset from shaft center line desired. Delivered air pressures to 3 psi. are available. Standard models range to 200 hp.

For further information circle No. 6 on literature request card on p. 32B



THE IRON FIST IN A *Velvet Glove*

Supposing—just supposing—YOU could write the specifications for an ideal blastcleaning chilled shot and grit. What qualities would you specify? You'd want it to be hard, of course, so it would clean fast. But you wouldn't want it so hard as to wear out your equipment at a rapid rate. Neither would you want the shot to be hard AND BRITTLE.

The ideal chilled iron shot and grit would be hard enough to do a fast cleaning job. And, if possible, you would want the hard iron carbides (that do the cutting) imbedded in some soft material that would go easy on your equipment and keep the shot from shattering into small ineffectual fines. What you would want is a sort of an "iron fist in a velvet glove" kind of shot and grit.

It may come as a surprise to you that there *is* such a shot and grit made. A chilled iron shot that holds the iron carbides in a *ductile matrix*—a shot that is hard enough to clean fast, yet soft enough to spare equipment and keep the shot from shattering too quickly. It is National Controlled "T" Shot and Grit.

We're not going to make any wild claims—we know YOU can appreciate the advantages of such shot and grit—providing what we say is true. And we'd like to prove our case *in a matter of minutes*—if you'll let us. Please write your name and address on the lines below and mail the coupon to the nearest Hickman-Williams office. The most you can lose is the cost of postage, but you may profit to the tune of a substantial sum of dollars.

NATIONAL CONTROLLED "T" SHOT AND GRIT *IS PRODUCED EXCLUSIVELY BY*
NATIONAL METAL ABRASIVE COMPANY • CLEVELAND, OHIO
WESTERN METAL ABRASIVES COMPANY • CHICAGO HEIGHTS, ILL.
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OK. Let's see you prove your point . . .

Name ______________________

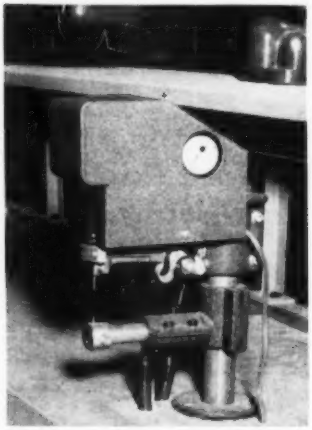
Firm ______________________

Address ______________________

City ______________________

MAIL TO HICKMAN, WILLIAMS OFFICE NEAREST YOU

WELDING EQUIPMENT: Raytheon Mfg. Co. announces a new Model 1-S welding head and a Model T-1 "weldpower" control. The welding head is designed for assembly of small parts of ferrous or nonferrous metals.



Advantages claimed are accurate electrode pressure, instantaneous follow-up and flexibility in application. The T-1 weldpower is a complete a.c. power control to be used with the 1-S head. It consists of a control unit and a transformer. The 1-kva. control operates on 115 v., 60 cycles, single phase, 0.5 ampere current; the transformer on 115 to 230 v., 60 cycle, single phase.
For further information circle No. 7 on literature request card on p. 32B

EXTENSOMETER: A new type extensometer designed for accurate tensional tests of bolts without the influence of shifting of grips or seating of the specimen is announced by Baldwin-Lima-Hamilton Corp. The new instrument was developed by R. H. Pinkel, research metallurgist, International Harvester Co., for testing the many sizes of threaded bolts required by that company. Slight refinements have been added by Lawrence Hyde, O. S. Peters Co., to provide unrestricted movement of extensometer arms. Since the method of attaching extensometer arms to standard cylindrical specimens cannot be applied to threaded bolts, attachment has sometimes been made on the grips. Any shifting of the grips and seating of the specimen, therefore, distorts extensometer measurements. To avoid the possibility of such errors the new extensometer has been designed to contact the center of the ends of the bolt, thus making direct and exact measurements of elongation. If the extensometer is left in position until actual fracture of the bolt, a complete load-elongation curve can be obtained, showing ultimate strength and over-all elongation.
For further information circle No. 8 on literature request card on p. 32B

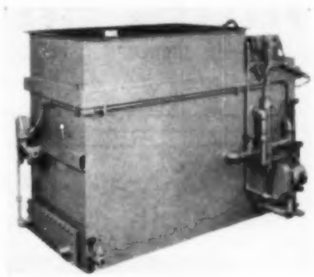
CUTTING COMPOUND: Solution of the problems of milling and machining stainless and other alloy metals through the successful use of C-5 cutting compound is announced by Felt Products Mfg. Co. The use of C-5 is an extension of its successful use with these metals in high-temperature thread compound applications. The new compound is recommended for boring, turning, tapping, threading, broaching, grooving, sawing and other metalworking operations.
For further information circle No. 9 on literature request card on p. 32B

HEAT TREATING FURNACE: The Cooley Electric Manufacturing Corp. announces the addition of a new larger size Type BL electric box furnace to its line. This is now offered with a chamber size of 15 x 12 x 30 in. It employs the Cooley embedded type of heating unit which protects the heavy element wire from atmospheric attack. The elements, formed in ceramic slabs, are located in each side, the bottom, top, rear wall and the door of the furnace to give a maximum and uniform distribution of heat.
For further information circle No. 10 on literature request card on p. 32B

COLORING ALUMINUM: A new chemical process that in one operation permits the protection and coloring of aluminum in such colors as yellow, blue, green, gold, brass and many others is announced by Enthone, Inc. The coloring procedure consists of cleaning the aluminum part and then immersing it in a solution of Alumox 44 salts. Dyes can be added to the processing solution so that coating and dyeing occur simultaneously. It is claimed that with this new process, aluminum objects can be dyed shades of brass and gold, a matter of particular importance in view of the shortage of copper alloys. The process is not meant to be a substitute for electroanodizing and was designed as a means of rapidly producing adherent beautiful colors on aluminum. In most cases, the finish is covered with clear lacquer. Almost all wrought and cast aluminum alloys can be processed successfully.
For further information circle No. 11 on literature request card on p. 32B

TUMBLING MACHINE: The Grav-i-Flo Corp. has added a new model tumbling machine to its line of equipment. With two 18 x 40 in. i.d. compartments, the new model 36-2 machine offers increased capacity per area of floor space over previous equipment, permitting the grinding, deburring and finishing of metal parts in larger quantities in faster time cycles.
For further information circle No. 12 on literature request card on p. 32B

SOLVENT-VAPOR DEGREASER: A completely redesigned and improved hand-operated, solvent-vapor degreaser is announced by Detrex Corp. The production cleaning machines included in this new series, identified as VS-800, make use of nonflammable chlorinated hydrocarbon solvents, either trichlorethylene or perchlorethylene, for the complete and high-speed removal of oil and grease from all kinds of metal products. The usual cycle of operation is vapor cleaning, then flooding clean

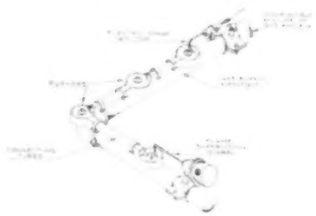


solvent over the work with a hand held spray lance, followed by the usual pure vapor cleaning phase which is characteristic of solvent-vapor degreasing. A minimum of floor space, lower working height, and an efficient new style solvent condenser are some of the improvements featured. A new, improved type of corrosion-resistant coating is applied to all interior surfaces of the VS-800 degreasers.
For further information circle No. 13 on literature request card on p. 32B

IMPREGNATION OF CASTINGS: American Metaseal Corp. announces a process for eliminating porosity in castings. Production cycle includes: degreasing, loading in autoclave, vacuum-pressure cycle, drainage of impregnant, cleaning and curing. Temperature resistant to 400° F., anodizing or plating can be applied after impregnation.
For further information circle No. 14 on literature request card on p. 32B

RUSTPROOFING: Moving parts made of iron and steel can get two-fold protection with a chemical treatment announced by Octagon Process, Inc. Known as "Rustshield 2", it is a phosphatizing compound which changes steel and iron surfaces to rustproof, highly absorbent non-metallic areas. Metal parts so treated will remain properly lubricated far longer than smooth steel surfaces. Rustshield 2 is usually applied to rubbing and sliding surfaces of precision parts such as thrust washers, pump pistons, gears, valve roller pins, stems and guides, as well as bearing surfaces of every type. Rustshield 2 meets the requirements for phosphate coatings in the U. S. Army Ordnance Specification 57-0-2C, Type II, Class A.
For further information circle No. 15 on literature request card on p. 32B

IGNITION SYSTEM FOR GAS BURNERS: The Burdett Manufacturing Co., manufacturers of industrial ovens and gas-fired burners, has recently been issued a patent for a newly developed system for igniting Burdett radiant-heat burners, assuring safety during the operation. The burners, arranged in series upon a gas supply manifold, are ignited at one end by an electric spark when a



manual push button is depressed. The closed circuit also energizes the automatic gas supply valve at the same instant, permitting gas to reach all of the burners by means of the gas supply manifold, and connecting tubes. A flame-supervising device is located at the last burner of the series, at the end opposite the spark igniter.
For further information circle No. 16 on literature request card on p. 32B

COOLANT: The newest industrial product developed by the makers of Johnson's wax is a wax coolant formulated especially for use with power hack saws and routers. When used with a power hack saw, Johnson's No. 170 wax coolant multiplies the life of saw blades many times. The coolant, a nonflammable aqueous wax emulsion, has excellent cooling properties and provides effective lubrication. The wax coolant greatly reduces wear of router bits when used with radial arm routers, and eliminates much of the welding and burring on routed edges. When degreasing is necessary, the residual coolant can be removed from the metal in conventional vapor degreasers or in alkaline washers. This product is not intended for use in machines which have return systems.
For further information circle No. 17 on literature request card on p. 32B

HARDNESS TESTER: Peabody Industries, Inc., have perfected a new technique for testing surface hardness of nonferrous extrusions, castings, machined parts and fabrications. First of its type to be manufactured in this country for exclusive use on nonferrous material, this pocket-size surface hardness testing instrument weighs less than 5 oz. and measures under 5 in. in length. Outstanding features include direct-reading scales, one incorporating accurately correlated numerical equivalents of Brinell equipment. The Metalometer scale is graduated numerically in 100 equal divisions and is used as a comparator for all accepted nonferrous master specimens.
For further information circle No. 18 on literature request card on p. 32B

ELECTRODE OVEN: Full protection against moisture absorption is promised users of mineral-coated electrodes by the Philip Roden Co., manufacturers of the newly announced DryRod electrode oven. The new oven is a portable heated storage unit which provides control over the moisture content and temperature of electrodes at their point of use. The oven is basically a cylindrical, compartmented sheet metal unit which is heated by an 840-watt element operating off 110 or 220-v. circuits. A variable thermostat gives close control on temperatures up to 600° F.
For further information circle No. 19 on literature request card on p. 32B

What's New

IN MANUFACTURERS' LITERATURE

20. Abrasive Belt

4-page, illustrated bulletin describes advantages of new "61" contact wheel. Time charts show how new, specially designed rubber wheel provides longer belt life and increased cutting rate. *Carborundum Co.*

21. Abrasive Wheels

Data folders give operating suggestions and recommended grades of abrasive wheels for stainless alloys, for finishing and semi-polishing and other applications. *Manhattan Rubber Mfg. Div., Raybestos-Manhattan, Inc.*

22. Alkaline Etching Compound

Illustrated 4-page bulletin on a new type of alkaline etching compound for all aluminum alloys includes case histories. *The Diversey Corp.*

23. Alloy Brazing

Brazing News No. 54, "Low Temperature Brazing", covers silver alloy brazing with Easy-Flo and Silfos. Tells where and how to use these alloys to the best advantage. Shows many interesting applications; describes fast brazing techniques. *Handy & Harman.*

24. Alloy Steels

New 16-page, pocket-size booklet contains seven case histories selected from widely varied fields to demonstrate the versatility of alloy steels. *Republic Steel Corp.*

25. Aluminum Alloys

36-page book on analysis of aluminum, brass, bronze, alloy specifications. *Sonken-Galamba Corp.*

26. Aluminum Coiled Tubing

New booklet on a general-purpose aluminum coiled tube with numerous industrial uses now ready for distribution. *Aluminum Co. of America.*

27. Anodizing Racks

Folder gives data on aluminum racks with copper hooks, insulated for any anodizing solution. *National Rack Co., Inc.*

28. Arc Furnaces

42-page illustrated brochure on application of electric arc furnace to smelting and refining of ferrous and nonferrous metals. *Pittsburgh Lectromelt Furnace Corp.*

29. Automatic Polishing

14-page, illustrated brochure describes automatic equipment for polishing, buffing and grinding. *Murray-Way Corp.*

30. Beryllium Copper

Helpful engineering information contained in new monthly series of beryllium copper technical bulletins. *Beryllium Corp.*

31. Binder, Ceramic Type

Technical bulletin introduces new ceramic-type binder designed to replace soluble silicate binders in low hydrogen-type electrodes. *Foote Mineral Co.*

32. Blast Cleaning

New 4-page brochure explains a completely enclosed chamber in which large castings are cleaned by streams of centrifugally hurled abrasives. Illustrated. *Pangborn Corp.*

33. Blast Cleaning

16-page booklet analyzes basic problems involved in blast cleaning and peening operations. Measures effectiveness of metal abrasives. *Hickman, Williams & Co.*

34. Blowers

Bulletin No. 300-S illustrates, diagrams and informs concerning a new constant pressure turbo blower and properly selected piping. *North American Manufacturing Co.*

35. Bronzes

New folder giving tables of properties (hardness, tensile, fabrication, physical) as well as uses and forms and other data on Chase phosphor bronzes. *Chase Brass & Copper Co.*

36. Burners

14-page illustrated booklet displays full line of long flame burners for gas, for oil and for gas and oil. Complete diagrams and descriptions. *Bloom Engineering Co., Inc.*

37. Burners

Burner Catalog B-11 lists full line of standard burners from ribbon flame burner to simple, efficient soldering iron. Dimension tables, schematic drawings, output charts. *C. M. Kemp Mfg. Co.*

38. Carbon Analysis

Bulletin 319 describes the Combustron, electronic induction heater in two- or one-tube model for flexibility in analysis of low to high carbon content in alloy steel, cast iron and stainless steel. *Burrell Corp.*

39. Carbon and Graphite

New 20-page catalog describes and illustrates products made of carbon and graphite from porous to impervious for applications in metallurgical, mechanical, electrical, chemical and process fields. Many useful tables. *National Carbon Co.*

40. Carbon Test

Illustrated data discusses the melters carbon test for estimating the carbon content of molten steel in 40 sec. *Harry W. Dietert Co.*

41. Castings, Heat Resistant

4-page bulletin describes heat resistant castings produced in designs for a wide variety of applications, including conveyors, roller hearths, trays, and radiation tube assemblies. *Standard Alloy Co.*

42. Castings, Nickel Alloy Steel

32-page bulletin with over 100 illustrations reports on steel, cast to shape, as a reliable engineering material. Data on properties and applications of cast nickel steels are classified by industrial fields. *International Nickel Co., Inc.*

43. Castings, Nonferrous

Booklet available on sand and centrifugal bronze castings. *American Non-Gran Bronze Co.*

44. Castings, Steel

Pyrasteel bulletin describes chromium-nickel-silicon alloy for service economy in resisting oxidation and corrosion at temperatures to 2000° F. Also resists gases and most concentrated or dilute commercial acids. *Chicago Steel Foundry Co.*

45. Chemical Handbook

264-page chemical handbook, spiral bound, describes complete line of company's chemical products for exacting industrial uses. Formulas, tables, illustrations. *General Chemical Div., Allied Chemical & Dye Corp.*

46. Cleaner

Bulletin 74-15 gives data on all-electric steam detergent cleaning. Pressures to 200 psi. *Livingstone Engineering Co.*

47. Cleaner

Bulletins on Virgo descaling salt and Virgo molten cleaners. What they are, how they work, their advantages and how they fit into your operations. *Hooker Electrochemical Co.*

48. Cleaning Brushes

New booklet shows 12 actual case histories of how brushes provide thorough cleaning of welds, stainless sheet, hot cast iron, automotive parts, brass fixtures and others. *Pittsburgh Plate Glass Co., Brush Div.*

49. Cleaning and Buffing

"Barrel Finishing of Metal Parts" contains interesting data on barrel deburring, as well as methods of removing many kinds of burrs from sawing, drilling, milling and stamping operations. *Magnus Chemical Co.*

50. Cleaning Equipment and Materials

Series of attractively illustrated bulletins informs concerning dry cleaning process, degreasers, metal parts washers, degreasing solvents, emulsion and alkaline cleaners and rust proofing compounds. *Detrex Corp.*

51. Coatings and Packaging

New 43-page working data file provides valuable guide to better preservation and packaging. *Seal-Peel, Inc.*

52. Copper Alloy Tubes

An extensively illustrated 32-page brochure deals with causes of corrosion and means of combating them as well as choice of materials for condenser tubes. *Revere Copper & Brass, Inc.*

53. Cut-Off Wheels

6-page folder gives data, operating suggestions and grade recommendations of cut-off wheels for delta machines. *Manhattan Rubber Div., Raybestos-Manhattan, Inc.*

54. Cutting Oil

32-page bulletin of case histories on use of all-purpose base in various machining operations. *E. F. Houghton & Co.*

55. Cutting Oil

Facts on more efficient and economical plant operation through use of right lubricants described in "Metal Cutting Fluids" booklet. *Cities Service Oil Co.*

56. Cutting Oil System

Illustrated booklet gives data and charts on new cutting oil, dispensing jet and motor driven pump. Contains test results of overhead flood with conventional coolants vs. new twin development. *Gulf Oil Corp.*

57. Degreaser

Vapor degreaser OPNT described and diagrammed in folder. Data on different models. *Topper Equipment Co.*

58. Diffusion Pumps

Illustrated data sheet describes and charts characteristics of new diffusion pumps and provides data on forevacuum, fractionation, speed, baffles and installation. *Distillation Products, Inc.*

59. Dipping Baskets

Catalog B-7 illustrates and describes various kinds of dipping baskets and other processing carriers. *Rolock, Inc.*

60. Drawing Compounds

Folder describes new type of lubricant for cold forming and drawing of stainless steel, both austenitic and ferritic. *Hangsterfer's Laboratories, Inc.*

61. Drawing Compounds

4-page folder outlines the physical properties and applications of drawing compounds for every type of drawing operation. *E. F. Houghton & Co.*

62. Electric Air Heaters

4-page folder available on portable and built-in electric air heaters used in every industry and business. *Edwin L. Wiegand Co.*

63. Electric Furnaces

Illustrated brochure gives data on electric heat treating furnaces, melting furnaces, metallurgical tube furnaces, research furnaces and sintering furnaces. *Pereny Equipment Co.*

64. Electric Ovens

Data sheet displays new industrial portable high temperature electric ovens. Illustrated. *Grieve-Hendry Co., Inc.*

65. Electric Salt Bath Furnaces

Illustrated folders give data on salt bath furnaces for batch-type work and conveyorized-type work. *Upton Electric Furnace Co.*

66. Electrode Holders

Data sheets illustrate and describe complete line of electrode holders. Include price lists. *Wagner Manufacturing Co.*

67. Electronic Oxygen Recorder

Bulletin 50-829 explains the magno-therm electronic oxygen recorder. Measures fundamental indicator of combustion efficiency. Many industrial uses. *The Hays Corp.*

68. Fasteners

Descriptive and illustrative 17-page bulletin on types, sizes and applications for rivets and riveting tools. Many useful engineering charts. *B. F. Goodrich Co.*

69. Fasteners

12-page illustrated pamphlet describes designs for cold-heading and shows special cold-headed parts for military applications. *Townsend Co.*

70. Ferro-Alloys

"Electromet Products and Service" gives helpful information about the use of ferro-vanadium and other alloying metals. *Electro Metallurgical Co.*

71. Finishes

New brochure gives full details on Black Magic Type A, blackening process for iron and steel. *Mitchell-Bradford Chemical Co.*

72. Flow Meters

Catalog C-12 gives complete line of meters and accessories for measuring pressure, vacuum and differential pressure of liquids and gases. *Meriam Instrument Co.*

73. Forging Furnace

Data available on new slot-type, 9-ft. forging furnace. Temperatures to 2900° F. Design adapted to various billet sizes. *Ra-Diant Heat Refractories, Inc.*

74. Forgings

16-page illustrated pamphlet follows a forging from the electric furnace through forge shop, heat treating, machining and inspection. *National Forge and Ordnance Co.*

75. Forgings

New catalog 51 contains 30 pages covering such topics as type of forgings; where and how to use forgings; turnbuckle dimensions, strengths and related data. Well illustrated with tables and drawings. *Merrill Bros. Co.*

76. Forming

Special bulletin of metal spinning, stamping and fabricating facilities. *C. A. Dahlin Co.*

77. Foundry Coatings

Illustrated brochure has information concerning foundry practices as related to the use of colloidal graphite in mold washes, pattern coatings, core coatings, chill coatings. *Acheson Colloids Corp.*

78. Fuel-Air Ratio Control

Metered control of fuel-air ratio in single and dual-fuel metallurgical furnaces is discussed in Instrumentation Data Sheet 4.3-4. *Minneapolis-Honeywell Regulator Co.*

79. Furnace Controls

Instruments and controls for heat treating furnaces are described in bulletin 49-750. *Hays Corp.*

80. Furnace, Maintenance Guide

A "Maintenance Guide for Electric Heat Treating Furnaces" has been prepared for electric furnace users. *Hevi Duty Electric Co.*

81. Furnaces

Illustrated bulletin available with complete description of new controlled atmosphere furnace. *Industrial Heating Equipment Co.*

82. Furnaces

High temperature furnaces for temperatures up to 2000°F. are described in leaflet. *Carl-Mayer Corp.*

83. Furnaces

New all-purpose furnace described in bulletin HD-646 may be used for carburizing, nitriding, dry cyaniding, bright annealing and clean hardening. *Hevi Duty Electric Co.*

84. Furnaces

Full information furnished on new gas-atmosphere high-production furnace for handling bright annealing of wire, strip and bar stock of copper and nonferrous copper alloys. *Holcroft & Co.*

85. Furnaces

Catalog D3 for descriptive matter on tool hardening equipment Model YP (vertical type) and Model 2Y. *Sentry Co.*

86. Furnaces, Annealing

Illustrated booklet on continuous vertical strip annealing furnaces, both single and multiple strand. *The Drever Co.*

87. Furnaces, Armor Plate

Illustrated 7-page booklet gives data on continuous hardening, pressure quenching, tempering line for steel plate. *The Drever Co.*

88. Furnaces, Small Tool

4-page folder describes complete set-up for the heat treatment of small tools, including draw furnace, quench tank and high temperature furnace. *Waltz Furnace Co.*

89. Gas/Air Mixer

4-page folder tells why gas/air mixers are suited for automatic brazing and soldering operations, flame hardening and as atmosphere units. *Gas Appliance Service, Inc.*

90. Gas Atmospheres

Illustrated bulletin on industrial applications of gas chemistry for heat treating. *Surface Combustion Corp.*

91. Gas Carburizer

Bulletin 1212 illustrates and describes No. 4 rotary gas carburizer for use with small parts. *American Gas Furnace Co.*

92. Gas Cutting Machine

New catalog available on Arco No. 50 Travograph gas cutting machine, equipped with three distinctly different tracing devices—manual, magnetic, or full-automatic Electronic Bloodhound to cut most intricate shapes from only an outline drawing. *Air Reduction Sales Co.*

93. Gas Sampling

16-page bulletin describing oxygen recorder and applications in sampling and analysis of atmospheres. Instrument based on paramagnetic properties of oxygen. *The Hays Corp.*

94. Grinding Machinery

Catalog 514 contains 28 pages of data and illustrations on continuous grinding machinery for fine grinding of innumerable metals. *The Patterson Foundry and Machine Co.*

95. Hardness Tester

4-page folder gives data on pocket-size hardness testing instrument. *Peabody Industries.*

96. Hardness Tester

Bulletin F-1689-1 tells of the Impressor, hardness tester for aluminum, copper, brass, bronze and plastics. *Barber-Colman Co.*

97. Hardness Tester

Illustrated circular describes portable hardness tester in sizes for work 1 in. to 6 in. round and flat. *Ames Precision Machine Works.*

98. Heat Processing

New bulletin answers questions: what is to be heated, what sections are to be heated, why the material is to be heated, to what temperature, the heating time. *Selas Corp. of America.*

99. Heat Treating

Booklet describes complete diversified facilities for steel, aluminum and magnesium heat treating. *Pearson Industrial Steel Treating Co.*

100. Heat Treating

"Surface Hardening of Stainless Steel", illustrated booklet, is available on request. *Lindberg Steel Treating Co.*

101. Heat Treating

Data Sheet lists complete line of heat treat services available at plant. *Vincent Steel Process Co.*

102. Heat Treating

4-page folder lists hardening and annealing services available for manufacturers of products and users of equipment made of stainless steel. *The Drever Co.*

103. Heat Treating

New booklet covers all methods of heat treat procedure available in plant. Includes bright hardening of stainless steels, steam treating. *Commercial Steel Treating Corp.*

104. Heat Treating Equipment

Illustrated literature available on Heil impervious graphite "Norcordal" units. *Heil Process Equipment Corp.*

105. Heat Treating Fixtures

New catalog No. B-8 contains descriptions and photographs of 75 custom-built fabricated alloy heat treating accessories. *Rolock, Inc.*

106. Heat Treating Fixtures

Information on complete line of standard carburizing carriers that will handle odd-shaped parts of every type thru carburizing and quenching to finishing. *Pressed Steel Co.*

107. Heat Treating Furnaces

Performance charts on fuel fired or electric heat treating furnaces for hardening, tempering, annealing, normalizing, stress relieving, aluminum treating. Furnace design incorporates both convection and radiant methods of heating. *Standard American Engineering Co.*

108. Heat Treating Furnaces

Bulletin SC-153, illustrated in color, describes the fuel-fired batch and continuous furnaces used in production of small caliber ammunition. Back page contains handy reference table showing relation of heat treat furnace equipment to consecutive steps in production. *Surface Combustion Corp.*

109. Heat Treating Guide

Chart guide constructed on slide rule principle for simplified hardening and drawing of tool steels. *The Carpenter Steel Co.*

110. High-Temperature Alloys

"Inco High Temperature Work Sheet" provides valuable information and suggestions for solving high temperature problems in design and production. *International Nickel Co.*

111. Immersion Pyrometer

Folder N 33-640 (1) presents both immersion thermocouple and immersion rayotube equipment for molten steel temperature measurement in 275-ton openhearth furnaces down to 1000-lb. high-frequency induction furnaces. *Leeds & Northrup Co.*

112. Impregnation of Castings

Folder on six-step impregnation process to eliminate porosity in castings. Includes data on impregnating material. *American Metaseal Corp.*

113. Induction Heating

Illustrated bulletin on low-frequency (60 cycle) induction heating furnace. Fully descriptive with applications. *Magnethermic Corp.*

114. Induction Heating

New 12-page, two-color bulletin on equipment for induction heating. Describes components and requirements for hardening, brazing, and annealing at 1000, 3000 and 10,000 cycles. *General Electric Co.*

115. Induction Heating

New bulletin "Induction Heating and Melting" contains the well-known Selector Chart and table giving heating and melting speeds for standard induction equipment. *Ajax Electrothermic Corp.*

116. Induction Heating

Bulletin giving specifications for electronic heater with frequency of 400,000 cycles. *Lewis Machine Co., Inc.*

117. Induction Heating

Bulletin 1440 furnishes full details on the "Checklite" system for safety control through the use of oversized components built into every unit for longer service life and uninterrupted production. *Lindberg Engineering Co.*

118. Induction Heating

Illustrated bulletin on new 60-cycle induction furnace for heating aluminum, magnesium, copper and brass for forging, extrusion and rolling. *Loftus Engineering Corp.*

119. Induction Heating

"Induction Heating . . . . the machine tool that makes tall stories come true" presents case histories of how induction heating has increased production, reduced space and cut production costs. *Westinghouse Electric Corp.*

120. Induction Heating Equipment

General data folder informs concerning megacycle tube-type machines for soldering, brazing, bombarding, annealing and hardening. Fully illustrated. *Sherman Industrial Electronics Co.*

121. Induction Melting

New bulletin 14-A tells how to master melting problems with a combination of melting speed, superfine control, and over-all economy provided by the Ajax-Northrup 20-kw. converter-operated induction furnace. *Ajax Electrothermic Corp.*

122. Inspection Light

Literature available on instrument that spotlights the work and magnifies it at the same time. For inspection. *E. W. Pike & Co.*

123. Instruments

New, 28-page catalog No. 5000 describes the principal instruments, control devices and related components manufactured by the company. *Minneapolis-Honeywell Regulator Co.*

124. Laboratory Equipment

Data available on complete line of spectrographic equipment. *National Spectrographic Laboratories, Inc.*

125. Laboratory Furnaces

Series of data sheets give full information on complete line of laboratory furnaces for numerous metallurgical operations. *Boder Scientific Co.*

126. Lapping Machines

16-page booklet offers charts, illustrations and data on machines for automatic precision lapping of all materials in any production quantity. *Crane Packing Co.*

127. Lithium in Copper

Data available on effect of lithium on electrical conductivity and porosity of copper and its alloys. *Metalloy Corp.*

128. Load Testing

Bulletin 325 describes new Type P SR-4 tension load cells based on SR-4 bonded resistance wire strain gages for load measurement. Gives specifications for load cells of four capacities between 10,000 and 100,000 pounds. *Baldwin-Lima-Hamilton Corp.*

129. Load Testing

Brochure 501 gives full details on universal testing machines in three ranges: Model TMU-A, 0-30,000, 0-6000, 0-600 lbs.; Model TMU-B, 0-15,000, 0-3000, 0-300 lbs. *National Forge & Ordnance Co.*

130. Machining Alloy Steels

24-page bulletin (11 tables, 7 detailed drawings) helps determine satisfactory and economical combination of microstructure, tool form, cutting speed and rate of feed for each type of machining operation. *International Nickel Co., Inc.*

131. Magnesium Die Castings

Book, "How Magnesium Pays", gives case studies of the economical uses of magnesium in a wide range of products. *Dow Chemical Co.*

132. Metal Cleaning Equipment

Product information folder gives data on industrial metal cleaners for use with water in either still tank or spray washing equipment. *Solventol Chemical Products, Inc.*

133. Metallograph

Revision of catalog will include the new metallograph with polarizing and phase attachments. Now in preparation for early release. *American Optical Co.*

134. Metallographic Polishing

Booklet describes two-speed polishers. Units available for flush or table mounting and in single, double or triple unit tables. *Buehler Ltd.*

135. Metallographic Polishing

4-page folder describes the advantages of diamond abrasives for polishing metallurgical specimens. Offered in 3 different particle sizes, all in 5-gram and 18-gram gun applicators. *Buehler Ltd.*

136. Metal Statistics

"Metal of the Month" letters, include market trends, statistics and other helpful data. *Belmont Smelting & Refining Works, Inc.*

137. Micro Hardness Tester

Bulletin describes the Kentron microhardness tester. *Kent Cliff Laboratories.*

138. Nickel Cast Iron

Bulletin describes eight types of Ni-Resist, gives applications and comparative service data in many industrial fields. *International Nickel Co., Inc.*

139. Nondestructive Inspection

Data available on electronic inspection equipment, demagnetizers and comparators for sorting. *Magnetic Analysis Corp.*

140. Nondestructive Inspection

Series of bulletins give data on both ultrasonic and magnetic nondestructive testing instruments. Illustrated. *J. W. Dice Co.*

141. Perforating Dies

Illustrated 40-page book gives diagrams, charts on set-ups for adjustable dies for perforating materials up to and including ⅛ in. mild steel. *S. B. Whistler & Sons, Inc.*

142. Photoelastic Stress Analysis

Revised edition of "Photoelastic Stress Analysis" shows the engineer why this method is effective for solving problems of stress distribution. *Eastman Kodak Co.*

143. Photomicrography

Full information furnished on Aristophot camera with Ortholux research microscope, providing the perfect team for easy, inexpensive photomicrography and photomacrography. *E. Leitz, Inc.*

144. Plating Barrels

4-page folder illustrates and describes the Daniels plating barrel designed to handle any barrel plating problem quickly and easily with a unique contact arrangement for maximum current distribution. *Daniels Plating Barrel & Supply Co.*

145. Plating Generators

Catalog MP-700 describes M-G set for electroplating, anodizing, electrocleaning, or electropolishing in either large or small-scale operations. *Columbia Electric Co.*

146. Plating Racks

8-page, illustrated booklet offers data on a plating rack designed to make the spline section or body of the plating rack a permanent tool. *National Rack Co., Inc.*

147. Potentiometers

Bulletin B15-13 discusses the characteristics of the measuring circuits used in the electroniK potentiometer. B15-12 discusses amplifier and motor combination. *Minneapolis-Honeywell Regulator Co.*

148. Precision Casting

12-page, illustrated booklet on precision casting with emphasis on the most widely used equipment and supplies. Check list of applications in various fields includes. *Alexander Saunders & Co.*

149. Precision Casting

4-page folder on cost reduction through investment castings. *Casting Engineers, Inc.*

150. Precision Castings

8-page, illustrated brochure gives informative engineering data on precision castings produced by the Mercast process. *Alloy Precision Castings Co.*

151. Presses

Press owner's manual contains complete operating and maintenance instruction for latest design straight-side double-crank presses. *E. W. Bliss Co.*

152. Presses, Bending

Steelweld presses for bending, forming, blanking, drawing and multipunching operations are described in catalog No. 2010. *Cleveland Crane & Engineering Co.*

153. Presses, Punch

Catalog TC describes line of twin-column punch presses. *Wales-Strippit Corp.*

154. Product Index

Bulletin listing research facilities available at company for solving metalworking problems. *E. F. Houghton & Co.*

155. Product Information File

Entirely new "Product Information File" informs, comprehensively, on time-tested industrial germicides and fungicides. Tells how to bring effective, economical microbial control to plants. *The Dow Chemical Co.*

156. Production Heating Equipment

4-page folder illustrates production equipment for brazing, soldering, anneal hardening. *Gas Appliance Service, Inc.*

157. Pyrometers

Data sheets available on high resistan cating pyrometers. Also pyrometer cont resistance thermometers. *Taco West Corp.*

158. Quenching Additive

New quenching additive described in "Q Story" along with other heat treating com *Aldridge Industrial Oils, Inc.*

159. Quench Oil Cleaning

16-page brochure of case histories on ec obtained by oil purification. *Honan-Cra*

160. Recorder

Detailed Bulletin 407 and Data Sheet AE contain facts about dew point systems for recording or recording-controlling. Wi of working temperatures. *Foxboro Co.*

161. Recorder, Strip Char

Bulletin C2 describes capacilog stri recorders that provide permanent record perature or other variables in industrial pr *Wheelco Instruments Co.*

162. Refractories

20-page booklet gives technical inform a basic nature on super refractories. text, charts, tables, illustrations and ap data. *Carborundum Co., Refractories Di*

163. Refractories

New 11-page bulletin on castable ref containing product descriptions, applicati charts for applications. Profusely ill *Laclede-Christy Co.*

164. Rhodium Plating

Directions for rhodium plating, with p reference to its use as replacement for t plating metals. *Baker & Co., Inc.*

165. Rod Selection Guide

Bulletin "SG" breaks down into basi tions the parts that can and should be h for longer life. Includes the part-na recommended rod, sizes and method of ap *American Manganese Steel Div.*

166. Roller Dies

Data sheet gives information on roller forming tubes, pipe and cold rolled shapes roll forming machines. *American Roller*

167. Rolling Mill Equipm

Illustrated 50-page catalog for rolli and accessories. Also numerous engineeri *E. W. Bliss Co.*

168. Rolling Mills

42-page, illustrated book on developme continuous strip mill and other equip processing ferrous and nonferrous metals *Engineering and Foundry Co.*

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169. Rust Preventives

10-page booklet on surface active agents useful as additives in the field of rust preventives. Chemical properties and availability of various oxygenated hydrocarbons. *Alox Corp.*

170. Rust Preventive Use Chart

A new rust preventive use chart No. 1151 lists the latest U.S. Government spec for preservative oils and coatings for packaging of government contracts. *Nox-Rust Chemical Corp.*

171. Shears

Bulletin 80F-A offers detailed information on operation of foot shears useful for numerous applications. *Niagara Machine & Tool Works.*

172. Spray Booths

Bulletin has 15 pages of photos, diagrams and information on hydro-whirl spray booths in all sizes and arrangements for manual or automatic spraying. *Peters-Dalton, Inc.*

173. Spring Steel

Handbook describes various spring steels and gives tolerance tables, heat treatment and physical property tables and fabrication data. *A. R. Purdy Co., Inc.*

174. Stainless Steel

"Fabrication of 17% Chromium Stainless (Type 430)" illustrations of typical changes in die practice, weld structures, mechanical properties of fusion welded joints and spot welds. *Armco Steel Corp.*

175. Stainless Steel

120-page reference book, cloth bound, on properties, selection, treatment, and fabrication of stainless steels. Wrought forms and castings; high and low temperature properties. Many tables. *Allegheny Ludlum Steel Corp.*

176. Stainless Steel

Weekly lists with analyses of all plates in stock and latest data. *G. O. Carlson, Inc.*

177. Stampings

26-page booklet contains reprint of paper on "How Modern Stamping Techniques Can Help Conversion". *Leake Stamping Co.*

178. Steam Drop Hammers

Profusely-illustrated 24-page brochure describes construction of steam drop hammers. *Erie Foundry Co.*

179. Steel, Aircraft

New printing "Aircraft Steels" booklet which includes revised military specs to August, 1951. Also sizes and analyses of aircraft steels carried in stock. *Joseph T. Ryerson & Son, Inc.*

180. Steel Bars

New wall chart of 275 different grades of standard, special and alloy steel bars shows chemical analyses and other data. *LaSalle Steel Co.*

181. Steel, Low-Alloy

Booklet on Hi-Steel, which has nearly twice the working strength of ordinary steels plus the ability to stand up under impact loads. *Inland Steel Co.*

182. Steel, Low-Alloy

Well-illustrated, 8-page folder on N-A-X low-alloy steels lists physical properties and test specifications. *Great Lakes Steel Corp.*

183. Stress-Relieving

New 4-page catalog folder describes how many unnecessary cleaning operations can be eliminated by new, practical, steam homo method for stress-relieving of small brass parts. *Leeds & Northrup Co.*

184. Subzero Freezer

4-page folder on portable freezer, 110-volt a.c., operating to −180°F., for shrink fitting, hardening, stabilizing, testing. *Webber Appliance Co., Inc.*

185. Surface Hardening Compounds

6-page booklet gives information concerning non-poisonous, non-explosive and non-inflammable surface hardening compounds. Illustrations and engineering charts. *Kasenit Co.*

186. Temperature Control

New catalog of improved pyrometer supplies gives data on thermocouples, protection tubes, thermocouple and lead wire, insulations and terminal heads. *Arklay S. Richards Co., Inc.*

187. Testing

Literature available on tensile and Brinell testing machines. *Detroit Testing Machine Co.*

188. Testing Equipment

New 80-page illustrated catalog lists testing and measuring equipment for laboratory and production line use. Photos, diagrams, descriptions of over 130 testing and measuring equipment. *General Electric Co.*

189. Testing Machine

New universal testing machine of 12,000 lb. capacity is presented in Bulletin 336. Illustrated. *Baldwin-Lima-Hamilton Corp.*

190. Testing Machines

Illustrated folder describes special features and operation of universal testing machine for tensile, compression and transverse tests. *Steel City Testing Machines, Inc.*

191. Textured Stainless

6-page illustrated folder on suggested uses for stainless metals to conserve strategic alloys and reduce weight for the armed forces. *Rigidized Metals Corp.*

192. Tool Maintenance

New compact 72-page booklet gives instructions on maintenance of alloy and high speed cutting tools. *Carborundum Co.*

193. Tool Steel Color Guide

Color guide to estimate the temperatures of heated steels has heat colors on one side and temper colors on the other side. *Bethlehem Steel Co.*

194. Tool Steel Selector

Handy, clearly printed, easy-to-use tool steel selector will be furnished on request. *Crucible Steel Co. of America.*

195. Tool Steels

198-page cloth bound reference book on tool steels. Types, properties, applications, selection, working, heat treatment. Bar, rod, forgings, cemented carbide, cast-to-shape tool steel. *Allegheny Ludlum Steel Corp.*

196. Tool Steels

New catalog available on Columbia tool and die steels. *Columbia Tool Steel Co.*

197. Tools, Stellite

Tool manual and catalog describes four different grades of cast cutting tool alloys. Gives physical, mechanical and chemical properties of alloys to help in selecting right tool alloy for various cutting operations. *Haynes Stellite Co.*

198. Tubing Chart

A chart covering the range of sizes of electric resistance welded tubing produced by company. *Babcock & Wilcox Tube Co.*

199. Turbo-Compressors

Bulletin No. 126-A describes the turbo compressor listing more than 160 standard capacities. *Spencer Turbine Co.*

200. Ultrasonic Testing

Commercial services using reflectoscope and reflectogage are described in bulletin 50-105-4. *Sperry Products, Inc.*

201. Vapor Degreasing

Pamphlet on properties and use of trichlorethylene as a solvent for vapor degreasing of metal parts. *Niagara Alkali Co.*

202. Vapor Pump Fluids

New data sheet describes vapor pump fluids for use in high vacuum equipment. *Distillation Products Ind.*

203. Welder, Bench

Bulletin DL-W-221 gives detailed description and technical data on new bench welder based upon an entirely new principle of operation. *Raytheon Manufacturing Co.*

204. Welding

New illustrated catalog describes gun, head and wires for automatic welding. On-the-job illustrations of applications. *Air Reduction Sales Corp.*

205. Welding

"Improved Design for Welding" describes the economies of good welding design as compared to haphazard design methods. *Linde Air Products Co.*

206. Welding Electrode Chart

New 4-page electrode selector chart lists the proper electrodes to be used in the welding of various metals. *General Electric Co.*

207. Welding Electrodes

16-page brochure, Bulletin AR51-1, "Alloy Welding Electrodes for Defense Production", describes electrodes for armor, high-temperature alloys, high strength steels and special applications. *Alloy Rods Co.*

208. Welding Equipment

Cadweld process and complete list of arc-welding accessories are described in catalog. *Erico Products, Inc.*

209. Welding Equipment

Welder's crayons for permanent markings on metal surfaces are described in folder. *Wm. Korn, Inc.*

210. Welding of Armor Plate

Booklet discusses new low hydrogen, ferritic electrodes for welding armored ships and tanks. *Arcos Corp.*

211. Welding Stainless Steels

"The Welding of Stainless Steels" devotes 48 pages to arc welding. Includes metallurgical background and specific uses of alloying elements. *McKay Co.*

212. Wire, Nonferrous

4-page folder contains wire gauge and footage chart and information on beryllium copper, phosphor bronze, nickel silver, brass and aluminum wire. *Little Falls Alloys, Inc.*

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METAL PROGRESS, 7301 Euclid Avenue, Cleveland 3, Ohio

January, 1952

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26	54	82	110	138	166	194	
27	55	83	111	139	167	195	
28	56	84	112	140	168	196	

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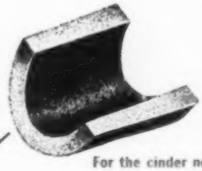
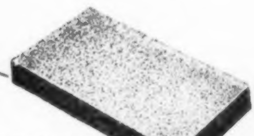
USE NATIONAL CARBON

TRADE-MARK



For the cinder notch liner!

For the cinder notch plug!



For the splash plate!

For the runout troughs!

For the skimmer plate!

● "National" carbon is now firmly established for blast furnace linings. It is being used outside the furnace as well—wherever there is contact with molten material—for the splash plate, runout troughs—clear down to the ladle—skimmer plate, cinder notch liner and cinder notch plug.

The reasons?

"National" carbon has no melting point. It is highly resistant to slag attack and thermal shock . . . not wet by molten metal . . . has a low thermal expansion . . . and maintains its mechanical strength at elevated temperatures.

Use "National" carbon inside and outside your blast furnaces and you cut down maintenance, speed up production and save money. For more information, write to National Carbon Company, Dept. M.

The term "National" is a registered trade-mark of Union Carbide and Carbon Corporation

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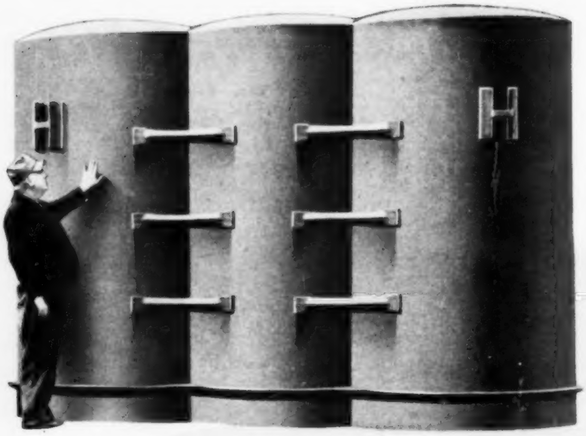

PSC

Light-Weight ANNEALING EQUIPMENT *in Any Size*

From mammoth covers requiring a flat car for shipment to midget boxes you can hold on a hand, PSC annealing equipment is made in any size that will help you get minimum handling time and maximum furnace capacity. Efficiently sized PSC containers recently increased by 100% the output of the furnaces of a well-known malleable foundry. In each furnace 22 stands of PSC light-weight sheet alloy boxes replaced 18 stands of bulky, space-wasting cast boxes, resulting in doubled capacity.

Heat-Treating Equipment for Every Purpose

Carburizing and Annealing Boxes
Baskets · Trays · Fixtures
Muffles · Retorts · Racks
Annealing Covers and Tubes
Pickling Equipment
Thermocouple Protection Tubes
Radiant Furnace Tubes & Parts
Heat & Corrosion Resistant Tubing
Tumbling Barrels · Tanks
Cyanide and Lead Pots

Weigh Up to 2/3 Less. Cut Handling and Fuel Costs.

PSC welded alloy units save time because, being 2/3 lighter than cast equipment, they handle faster; and require less time to attain pot heat. A recent study of one customer's cycle showed a total saving of 5 hours. By repeated records, their service life is 2 to 7 times that of cast units. Let our technical staff work with you in devising time-saving units. As pioneers of light-weight, sheet alloy, heat-treating containers and fixtures, we make available to you a wealth of designing and production know-how. We fabricate in any alloy. Send blue-prints or write as to your needs.

The Pressed Steel PSC

THE PRESSED STEEL COMPANY
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Industrial Equipment of Heat and Corrosion Resistant WEIGHT-SAVING *Sheet Alloys*

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SELL YOUR BRASS
MILL SCRAP PROMPTLY
To keep production rolling
Help lick the shortage of brass and copper. Make sure that every pile of brass mill scrap in your factory — even if it is only a hundred pounds — is sold at once.
Not only is this scrap immediately salable on today's market — it will bring vital metal to the production lines where it is sorely needed.
Both the defense program and civilian needs require more and more copper and brass. To prevent increased shortages and even more stringent regulations, see that *your* brass mill scrap is moved promptly.
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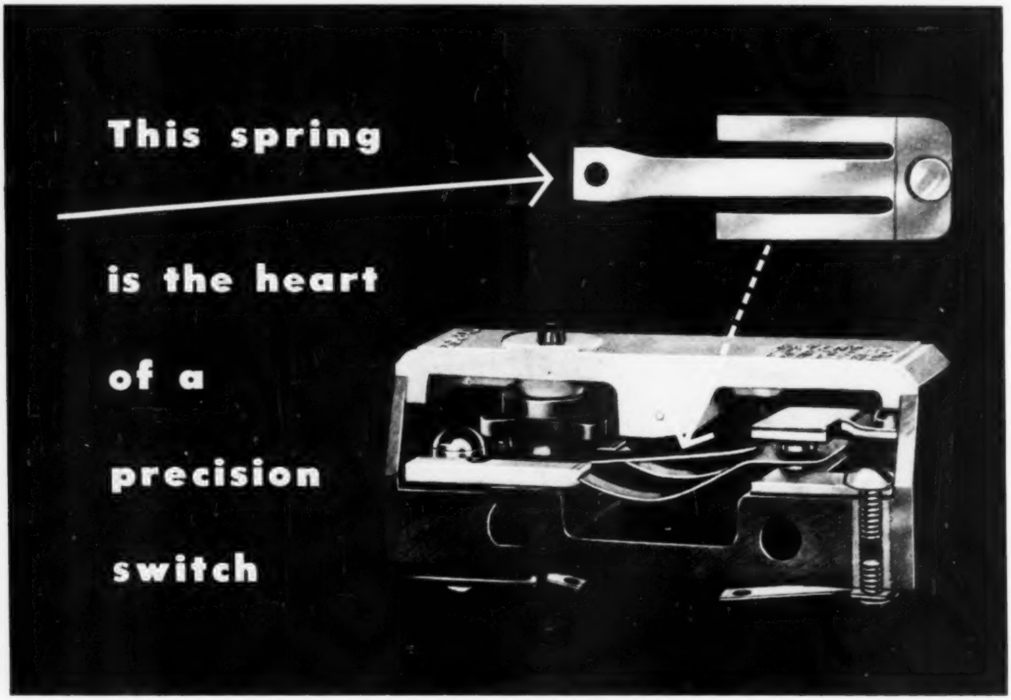

IT'S MADE OF BERYLCO BERYLLIUM COPPER

Designed for dependable operation over millions of cycles, this unit—manufactured by the Micro Switch Division, Minneapolis-Honeywell Regulator Company—is used in the most exacting modern equipment. In critical industrial applications, these switches control machine tools, business machines, instruments and materials handling equipment. In the present defense effort, they play an equally important role in weapons, ships, planes and tanks.

Berylco beryllium copper made possible the design of these switches. Berylco's high endurance strength permits the necessary spring action to be crowded into the required space. Its ability to be hardened after forming permits a one-piece blade. Its greater uniformity permits more constant operating characteristics.

The basic switch, shown here, has an Underwriters' listing of 15 amp., 125, 250 or 460 volts ac. Recent switches, so small that it takes 265 to make a pound, are rated at 5 amp., 125 or 250 volts ac. These are only two of some 5,000 catalog items which can be produced inexpensively and in mass-production quantities because of the desirable properties of Berylco beryllium copper.

It will pay you to find out what Berylco can do for you. Take advantage of the know-how of the world's largest producer. Write or phone any of the offices listed below.

VALUABLE ENGINEERING INFORMATION on Berylco beryllium copper is contained in a series of technical bulletins, published monthly. To receive your copy regularly, write on your business letterhead.

TOMORROW'S PRODUCTS ARE PLANNED TODAY WITH BERYLCO BERYLLIUM COPPER

Sample material available for testing purposes

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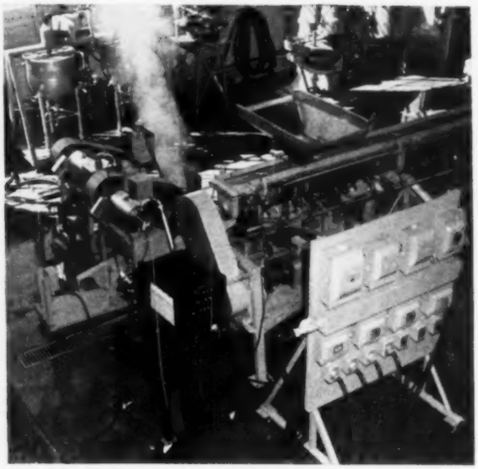
EFFECTIVE INSULATION—*Used in both research and quality control, these instruments automatically record temperatures at many points in a "test wall" of paper insulating material.*

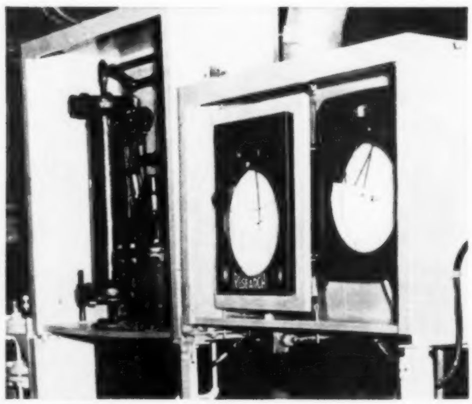


BETTER FOODS MEAN HEALTHIER BABIES—*Pilot plant at Baby Foods Division of Gerber Food Products makes use of* **ElectroniK** *recorder to check all-important processing temperatures during test runs.*

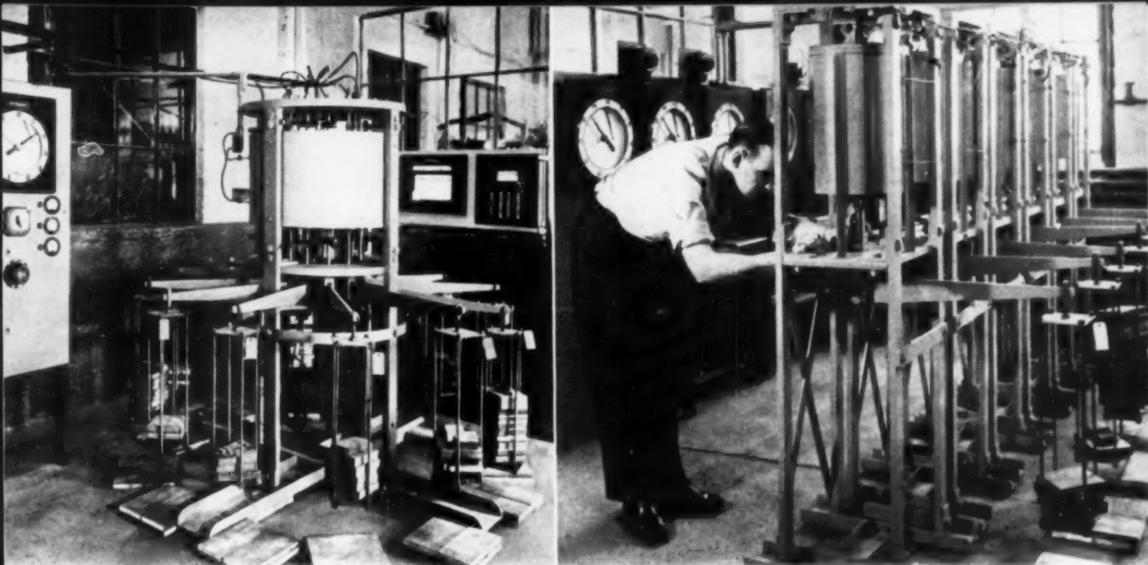
For all of industry... *especially*

Instruments

TORQUE MAGNETOMETER *used by researchers at United States Steel Corporation tells whether a steel sheet can be "drawn" into a deep cap for a ketchup bottle. Shape of curve drawn by recorder pen tells the magnetic, hence the shaping, story.*



FILAMENTS FOR FABRICS — *These instruments, in one of America's foremost rayon plants, are contributing to the stability of pilot plant processing in the development of finer filaments for tomorrow's fabrics.*



APPRAISING THE ALLOYS. *These two installations at the Watervliet Laboratories of Allegheny Ludlum Steel Corporation indicate the type of equipment and* **ElectroniK** *instruments used for "creep" and "time-to-rupture" tests on special alloys.*

for the metals industries

accelerate research

THE GREAT and growing laboratories of the metals industries evidence the prominent part played by research programs from which stem a never-ending stream of better products. And notable among the more important tools of the technician are the modern instruments and controls which accelerate research . . . help complete projects in days instead of months.

Yes, today's researchers get things done in a hurry. Thinner yet better quality tin coat, stainless clad carbon steel sheets, metals with such special qualities as resistance to rust and the ability to be deep drawn and an affinity for a firm bond with porcelain enamels . . . are but a few indications of how instruments and controls are helping speed new ideas from the drafting boards to practical realities in a minimum of time.

Brown instruments and controls, of course, have been playing a vital role in such research for many years . . . and, just as in production operations, will continue to keep pace with the increased demands of new techniques.

Our local representative will welcome the opportunity to discuss your instrumentation requirements . . . for research or full-scale production. Call him in today, he is as near as your phone.

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● *Important Reference Data*

Write for 84-page bulletin "Instruments Accelerate Research" . . . and Data Sheets on instrumentation for a variety of specific applications.

New Development in Salt Baths

Eliminates scale and decarburization on steels in neutral salt baths operating up to 2300° F.

NEUTRAL hardening in molten salt baths should mean just what it says. No scale or decarburization is present in a properly rectified neutral salt, regardless of temperatures used. This is possible at 1500° F. and up to 2300° F. A recent development by one of the leading salt bath suppliers makes this possible for the first time without the manual addition of solid deoxidizers. The Neutra-Gas Process (U. S. Patent No. 2474680) is simple, effective, and inexpensive. Merely bubble an inexpensive commercial gas through the molten bath for recommended periods. Neutrality is easily checked chemically or physically. The Neutra-Gas Process is operating at the present time in molten baths weighing less than 100 pounds and those holding several tons of salt.

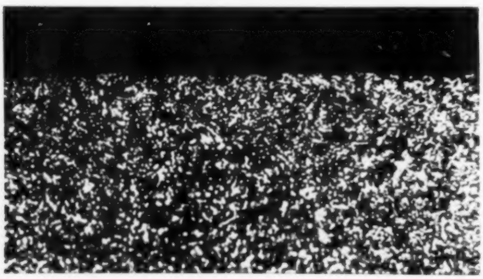
A truly neutral salt is the ideal medium for heating all steels with no surface effect. There is no atmosphere, and air is excluded while the work is heating. Scaling and decarburization are prevented. A thin film of salt protects parts right up to the quench. With neutral salts operating at 1500°-1600° F., Neutra-Gas is used for just a few minutes per shift. Sludging is practically eliminated; economies result because sludging removes good usable salt. The bath remains very fluid allowing rapid and uniform heating with less distortion. To obtain all the advantages of salt bath hardening, use salt baths for both heating and quenching The improved fluidity of the Neutra-Gas controlled neutral salt assists materially in isothermal quenching salt operations.

Neutral Salts from 850° – 1850°

Various salt mixtures provide a wide range of usefulness in the heat treatment of steel. The Neutra-Gas is used with chloride mixtures only. The most popular type is Park Nu-Sal Neutral Salt. Its melting point is 1230° F. with a range of 1300°-1600° F. Most steel hardening temperatures fall within this range. Nu-Sal is widely used as the austenizing bath for isothermal treatments such as austempering and martempering.

Cycle annealing involves a wider range of temperatures. Park K-3 Neutral Salt melts at 1020° F. and is usable past 1700°; periodic use up to 1850° is permitted if proper rectification is made with Neutra-Gas.

Low melting salts are available for special purposes. Park's #800 Neutral Salt (melting point 850° F.) and Park #900 Salt (melting point 920°) are used for tempering, high speed steel quenching, and have a range up to 1700° F.



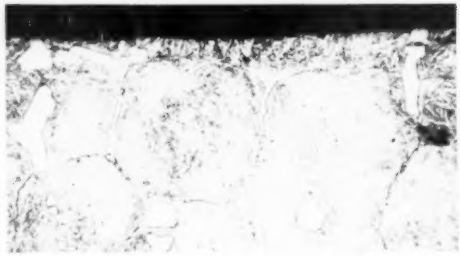
(X 500) Microphotograph of the edge structure on SAE 1095 steel treated for 60 minutes at 1450° F. in a commercial installation of Park Nu-Sal kept neutral with the Neutra-Gas process. (Sample quenched in caustic solution and tempered in No. 800 Neutral Salt at 1200° F.)

Baths operating consistently at 1700° to 1900° F. usually operate with less fuming and volatilization if their melting points and top operating temperatures are slightly higher. Park K-17, with a range up to 1900° F., also has a reasonably low melting point of 1175° F. Economy is indicated here as the temperature of an idle furnace may be kept at 1250°-1300° with very low power costs.

No Decarb on Moly High Speed Steels

Wider use of molybdenum high speed tool steels has virtually made the use of salt baths mandatory. During the last War it was salt baths which made possible the adoption of the molybdenum high speed steels in place of the very critical tungsten types.

As in most instances, the increased use of a method leads to rapid improvements. The improved rectification of high heat salt baths operating from 2200°-2300° F. is a development of the Park Chemical Company laboratories. The Neutra-Gas Process was adapted to the higher temperature applications in order to reduce the oxides of the chloride salts. Metallic oxides are reduced by graphite rods immersed in the salt. Costly and laborious sludging has been nearly eliminated and electrode life increased. Size loss of tools is held to a minimum. It is possible to harden unground or finished tools. Scaling, decarb, oxidation, pitting and other surface defects are automatically avoided. Distortion is negligible. Immersion in salt seals out all atmosphere. Salt film protects work right through the quench. For pieces large or small, temperature is even and constant.

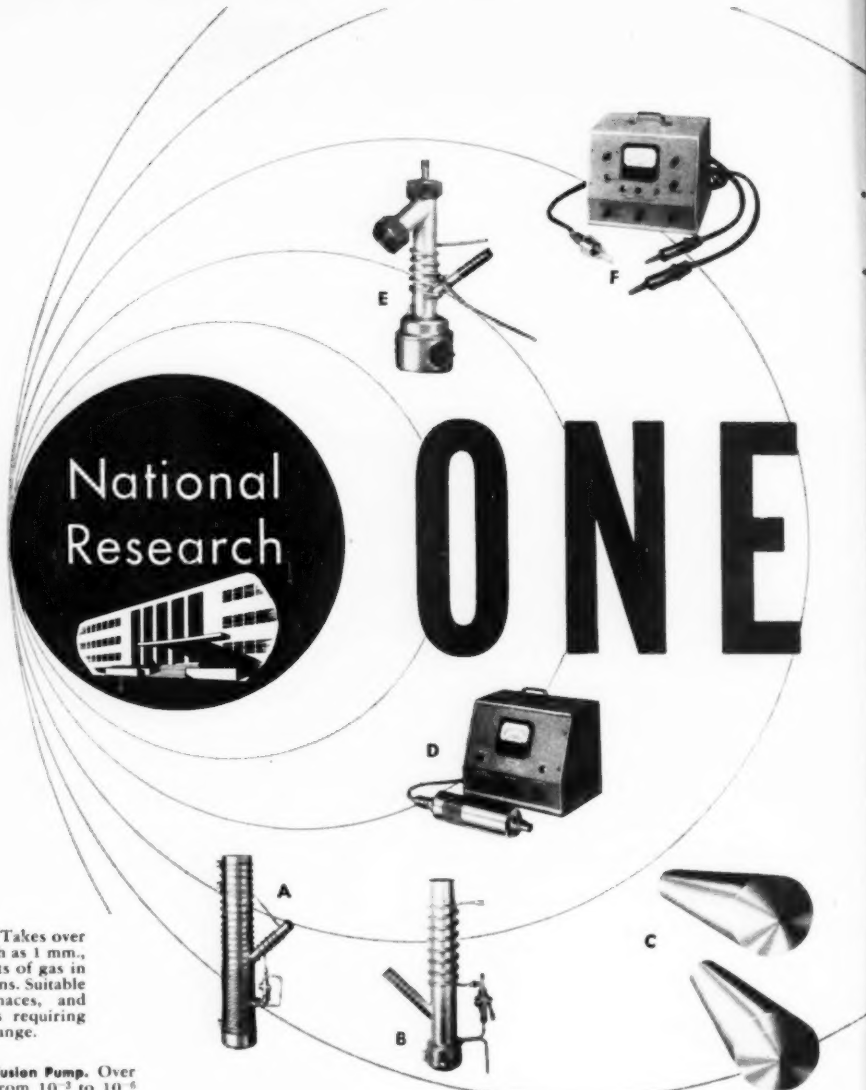


X500—(Reduced in Printing) Edge structure of high speed steel after several hours in a Park No. 175 Hi-Heat salt bath.

Process detail is preheat at 1550° F. in Park No. 117 Preheat Salt, high heat at 2200°-2350° F. in Park High Heat No. 175-S with Neutra-Gas. Quench in either No. 900 Neutral Salt, or in No. 100 Quench Salt which contains a small amount of cyanide. Tempering in salt completes the cycle, free from any deleterious effect caused by contact with the atmosphere.

Park's salt baths, and the knowledge of how to make them do a better job for you, can effect economies in your heat treat department. Write, telling us in detail your application, and we will send you the technical bulletin that covers your particular operation. There is a Park field engineer to assist you, backed by a technical staff and 40 years of Park Chemical Co. service to the heat treating industry. Park Chemical Company, 8074 Military Ave., Detroit 4, Michigan.


REPLACED
and SAVED
$50.00 a TON...
...on this
Winch Shaft with –



(A) B-4 Booster Pump. Takes over at forepressures as high as 1 mm., handling large amounts of gas in range of 1 — 30 microns. Suitable for evaporators, furnaces, and other vacuum systems requiring high capacity in this range.

(B) H-2-P Purifying Diffusion Pump. Over 50 liters per second from 10^{-3} to 10^{-6} mm. range. Operates against forepressures as high as 0.300 mm. Blank-off 2×10^{-7} mm.

(C) Gas Free High Purity Metals. Copper, nickel, cobalt and iron. Special melts on request. Ingot weights up to 600 pounds.

(D) Alphatron* Vacuum Gauge. Accurate gauging from 10 mm. to 1 micron. A rugged metal ionization type instrument which can be adapted for recording, controlling, gas filling, and leak detection.

(E) B-1 Booster Pump. A small pump designed for rotary exhaust equipment used in miniature and subminiature tube production. Useful where a small pump is required to quickly obtain pressures in the region of one micron.

(F) Type 710 Thermocouple-Ionization Gauge Control. One instrument for scientific and industrial vacuum gauging. Incorporates two thermocouple gauges (1 — 1000 microns) and one ionization gauge (10^{-3} mm. to 10^{-8} mm. Hg. range) in one control. Automatic input regulation and protective circuit.

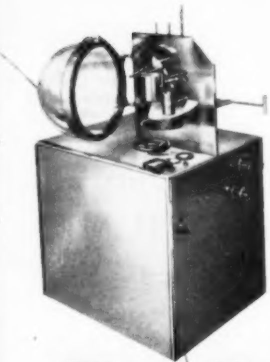
(G) Standard Vacuum Furnace. A versatile packaged unit to melt, pour, heat treat, degas, sinter, and anneal under high vacuum or controlled atmospheres. Temperatures up to 2000° C.

(H) Vacuum Seals. For introducing motion, power, or connecting gauges.

(I) High Vacuum Valves. Available in sizes ⅛" to 16". Low rate of leak.

(J) Vacuum Fusion Gas Analyzer. Analyzes metals and alloys, including titanium, for combined or dissolved oxygen, nitrogen, and hydrogen.

(K) Type 701 Thermocouple Gauge Control. A light, portable instrument for vacuum testing in range 1 — 1000 microns. Compact and rugged.



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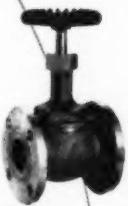

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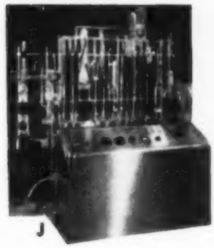

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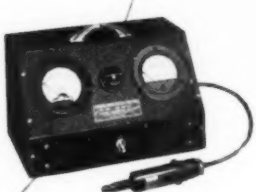

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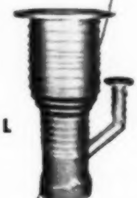

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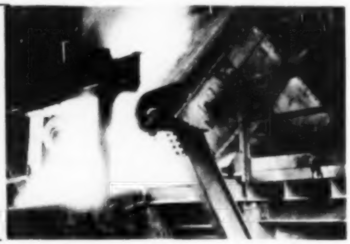

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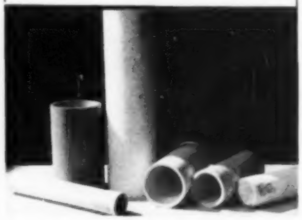

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Metal Progress

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Technical Articles

Departments

Abstracts of Important Articles

By Cyril Stanley Smith, Director, Institute for the Study of Metals, University of Chicago

Pure and Applied Science in American Metallurgy

Society has every right to demand of an individual that he make some contribution beyond the biological one toward the continuation or progress of civilization. Too often this question is phrased in a much narrower sense: "Does it pay our particular group to support this individual?" In this country it is the short-range economic criterion that is most frequently applied, yet the activities that are most important in the long run are often the very ones that certainly do not pay from a short-range viewpoint, and frequently appear at first to have no value whatever!

The creative works of a philosopher, poet or artist have little financial value, yet they are of very central importance in terms of giving shape to those aspects of the human activity which are furthest from animal origins. One rarely expects a philosopher or an artist to justify his existence in material terms, though one does require him to do imaginative work and to point out something of the relation between the human mind and the physical world. Among scientists, the astronomer alone is not expected to prove the value of his work, although most textbooks in astronomy start with an apologia including references to navigation and surveying. Chemists for centuries have been tolerated because their work was useful in making gold either directly by transmutation or indirectly by providing the basis of the industries that build or destroy things, or that clothe, feed or move people. As an esteemed member of the intellectual hierarchy, the physicist for many centuries has been free to do whatever he wants, but was ignored by the public until the last decade when the value of his work was suddenly realized; whereupon his efforts were soon supported in a big way, and as a result perhaps his real motive may have been destroyed by the emphasis on short-range values.

The metallurgist, from the earliest days when he first produced the bronze and the iron tools whose importance was sufficient to name whole eras of civilization, has been purely practical. The justification of his work has lain solely in its material products and not in what he thought about them. It is even true that the very basis of his success lay in his disregard of theory and his willingness to try empirical experiments guided by the intuitive understanding of materials that can come only from close and prolonged physical association with them. The feel of a piece of metal under the hammer, or its resistance to the engraver's burrin, transmitted directly to the artisan an intimate understanding of the properties of his material, and even a kinship with its nature, that no operator of a 10,000-hp. rolling mill or an automatic press can possibly approach.

Yet there is a limit to what a man can do in his lifetime, and empirical knowledge or experience cannot easily be transmitted to grow from generation to generation in the manner of a body of organized knowledge tied to a conceptual framework. Such a framework can be built up over vast periods of time and can be transmitted by virtue of its coherent structure and over-all pattern much more easily than individual experiences. It permits facts to be remembered and makes the significance of new information more immediately apparent.

Only a few fields immediately lend themselves to this idealized abstraction, and the growth of science has come from the unraveling of the significant component parts from the extremely confused and complex mass of information that is presented to us by our senses. The empirical stages of knowledge are generally developed by people with short-range motivation and unbounded but somewhat uncritical curiosity who collect data in isolated fields without regard to their connection with others. Such cataloging of natural and artificial phenomena is of enormous importance and is generally the first stage in any science. The scientist, however, seeks underlying laws applicable to all physical phenomena, and eventually it will be he who, by showing

the relation of any given observation with all others, makes previously complex relations simple. A few widely applicable concepts are themselves strengthened by their application in diverse fields.

In this century for the first time in history it is possible to attempt a description of the properties and behavior of metals in terms of the same concepts that apply to all other matter. The reason for the metallurgist's professional separation is economic, not scientific. Yet the metallurgist is much more than a scientist — he must also be something of a mechanical, chemical, and an electrical engineer, combined with some of the qualities of an artist, salesman, and politician! In the lack of suitable supermen, and in the face of the growing complexity of life generally, the profession has spawned adjectival subdivisions. There are few plain "metallurgists" today, but many physical metallurgists, metallurgical chemists, metallurgical engineers, production metallurgists, sales metallurgists and so on and on, in addition to those who seem proud to indicate that their knowledge is limited to ferrous metals, nonferrous metals, light alloys, plutonium, and what not.

SCIENCE, THE TAPROOT OF INDUSTRY

There is, I think, little doubt that through most of the past the fundamental approach of the physicist has been of little value to the metallurgist; in fact, the benefit of contact has been mostly in the inverse direction — the metallurgist's vast knowledge of matter and its behavior has provided the physicist with information on the properties and reactions of substances which have served both as a goal for explanation and as a check on his wilder speculations. There are few cases in past metallurgical history where a theoretical advance or a discovery made by a physicist working on fundamental solid-state problems has given rise directly to an important industrial innovation, while there have been many instances where a discovery made by purely empirical methods has stimulated the scientist. The chief current occupation of the solid-state physicist is aimed at bringing order to and explaining the facts long known to metallurgists, geologists and ceramists.

However, the influence of science, though indirect, has nevertheless been enormous. Whole industries have sprung up from the work of Wollaston, Davy and Faraday on the transport of electricity in solutions of metallic salts; modern industrial metallurgy would be impossible without the simple thermocouple which was discovered and at first studied solely for its scientific interest. It is very clear that the metals themselves, the methods of control, and the ultimate uses would all have been developed far more slowly had it not been for the growth of science.

It needed the horrifying example of the atomic bomb to bring home the fact that science is really profitable and useful, and to persuade the general public, the legislators, and those in charge of the purse of industry to encourage fundamental research.

Since the war, science (both applied and "pure") has been supported in a manner which is lavish compared with previous conditions, although it is by no means certain that the proper level has yet been established. In metallurgy, as in other fields, there has been a willingness to spend money liberally in industrial and in government laboratories, as well as in the universities; the limitation has become investigators rather than money. Not only the amount but also the type of research is radically changed. A few years ago it was common for a metallurgist to poke a bit of fun at the physicist. The few metallurgists working on subjects adjacent to physics were tolerated but not regarded as significant members of the metallurgical profession. Now, however, things have changed. At the 1951 Metal Congress in Detroit over 500 people attended a meeting of the A.S.M. at which three physicists — not metallurgists, physicists! — discussed the theory of crystal dislocations. Five years ago such attendance would have been unthinkable.

When anything becomes popular it is our duty to examine it critically and see if our concern should shift to other areas which are being neglected. Much lip service is paid to fundamental research nowadays. It should certainly not be done just because it is currently the thing to do and there may be money available. There is no field in which the premium on quality is higher; no man should ever be told to do fundamental research just because it is believed that it will pay off. An engineer who can do an excellent job of developing an alloy

or a machine by empirical methods may not have the peculiar combination of intuitive imagination, desire for intellectual order and willingness to check and reject ideas. People lacking these qualities should be discouraged from seeking a career in fundamental science. Most individuals are actually more interested in working on things of immediate apparent utility, and fortunately there is room for many more men working on such developmental and applicational jobs than on basic science.

THE URGENT NEED FOR PURE SCIENCE

The writer is associated with the Institute for the Study of Metals at the University of Chicago, which was organized at the end of 1945 to give form to the university's realization of the critical role of fundamental science and the relative deficiency of this country in that area. It is financed largely by contributions from industrial sponsors with minor, but valuable, support from the Office of Naval Research and the Office of Air Research, the balance coming from general university funds. The industrial sponsors are told that the faculty of the Institute will work on whatever aspect of the science of metals and related fields it thinks will be most productive of scientific understanding, and no specific projects are undertaken for industry. It is not an engineering school and cannot even give very useful advice on day-to-day problems.

Is this worthwhile?

At least our sponsors think so, for most of them are continuing their support beyond their original contract period. But what have we and the other universities with similar aims achieved?

The new alloys that have been developed for jet engine application are not an outgrowth of fundamental science but an outgrowth of empirical experiment by wise, experienced metallurgists. The new casting and fabrication methods again owe nothing to science and everything to skilled metallurgical engineers. Titanium is being made — albeit not very elegantly — by people motivated by a vision of its utility. Boron is being used in steel to save large amounts of alloying elements, applied by those who know how to use it, and not by those who know why it works (indeed, there are none of the latter). The metallurgical scientist cannot feel very encouraged when he sees how little he has been directly involved in all of the important recent achievements of the metallurgical industry. Is his work of any use at all, or is it just a harmless, decorative occupation?

The answer to this question lies in whether those who are doing the engineering jobs, those who are developing alloys for specific purposes and using old ones in a manner hitherto impossible are helped in their work. Do their thoughts reflect in any way the progress in science? Does the current, slightly better picture of the nature and properties of a grain boundary help the practical metallurgist? A metallurgist has known for years what to expect when he looks through a microscope at the structure of a piece of metal; is he in any way helped by the new knowledge that these structures result mostly from the energy existing at the interfaces between the various grains and phases and are not characteristic of the crystals themselves that are so conspicuous under the microscope? Is a knowledge of the mechanism of diffusion and its relation to the various kinds of imperfection that can exist in a crystal of value in developing a high-temperature alloy or means of protecting the surface? Is the theory of dislocations and their interaction with impurity atoms of help to those planning practical studies of "stretcher strains"? Is a knowledge of the basic laws of the physical chemistry of equilibrium helpful in carrying out steelmaking processes in an openhearth or a bessemer converter?

Surely the answer to these and all similar questions is yes.

The more fundamental the research, or rather the understanding which results from research, the more certain it is to be of eventual use somewhere, but the less obvious its immediate utility. (Parenthetically, one must not always attribute inevitable, eventual utility to the apparently useless!)

In addition to the most valuable growth of basic understanding of metals one can also be quite confident that in the long run fundamental scientific research will discover important new principles which directly open up profitable technological areas. Although there has not been any such outcome in the strictly metallurgical field in recent years, there is in the closely allied field of solid-state physics.

Science in Metallurgy

The whole field of ferromagnetism is one in which theory and experiment have gone hand in hand in a most profitable manner. The new permanent magnet materials based on particles of iron so small as to constitute single domains are a direct outcome of theoretical studies of ferromagnetism. Though empirical methods would eventually have uncovered them (indeed, the magnetically hard, mechanically soft, two-phase iron-copper-nickel alloys are based on the same principle), many years were undoubtedly saved by the development of good theory. Furthermore, theoretical studies of semiconductors gave birth directly to the transistor, the new type of solid electronic "tube" which seems destined to revolutionize the electronics industry.

One must not expect things of like importance every few years, particularly in fields such as metallurgy in which vast amounts of empirical studies have already been made, but one can clearly see the value of increased understanding of phenomena that have been known for some time, and the improved framework of knowledge available to those who have specific jobs to do. The many ramifications of Zener's work on the "acoustic spectrum" of materials provide a case in point.

Starting from an initial interest in the relation between atomic position, stress and time, and considering this basically instead of from the point of view of an engineer attempting just to measure and use "damping capacity", Zener and his collaborators measured grain boundary viscosity, measured the time for the interchange of neighboring positions of atoms — the unit diffusion process — and learned much about the formation and motion of crystal imperfections. All these phenomena are of central importance in developing alloys for use at high temperatures. It is currently impossible to predict with certainty what kind of alloy will result on alloying any two or more metallic elements, but the search for the principles is progressing rapidly and in a few decades it will probably be possible to design an alloy with the certainty that one now designs a machine for a given purpose.

The dollar value for such knowledge will be enormous. Even our present rudimentary knowledge of the relative role of electron concentration and electronic energy levels, of atom size, and polarization factors, provides a firm basis on which to select alloys for experiments. Again, many apparently diverse factors empirically known in the past to those who have studied hot-shortness, sintering, solidification, brazing and stress corrosion cracking suddenly became part of a single picture when the role of surface energy in determining metal structures was formulated. None of these resulted in world-shaking discoveries; all of them have become an accepted part of the thinking of industrial metallurgists, and their influence must, in some degree, be reflected in the practical achievements of these laboratories.

DEVELOPMENT OF BROADER VISION

In the writer's opinion the most important change in the last decade or so has been the willingness on the part of industrial metallurgists to abandon the assumption that metals are unique. The metallurgist always knows special cases and can easily upset a pure theorist at any time, yet by mastering the framework of knowledge that applies to all things, he can concentrate attention on the abnormalities and make much faster progress. By becoming a scientist he can benefit by knowledge in many other fields. If he studies metals only as metals, without regard to what is known of the structure, deformation, strength and the electrical, magnetic and other properties of crystals and solids in general, he must relearn for himself much that is already known. The scientific metallurgist should be one who applies chemistry and physics to a specific case, not one who learns only those aspects which manifest themselves in the particular medium of his choice.

Though metallurgy is an extremely ancient profession, it is currently very far from static. The change comes partly from the demands of engineers for new materials of fantastic properties, and partly from the fact that it has only recently been realized that the achieved properties of metals are far from the potentially possible ones. Future developments will come most rapidly by a combination of men with practical experience and with a desire for a given result working closely with those who bring to bear on the understanding of metals the whole range of scientific knowledge of the behavior of matter.

By **Muir L. Frey**, Asst. to General Works Manager, Tractor Plants, Allis-Chalmers Mfg. Co., Milwaukee

Steel for Machinery; Yesterday, Today and Tomorrow

THE BEGINNING of a new year is, traditionally, the time to review and evaluate the progress of the year or years just past and then, perhaps, dust off the crystal ball and take a look into the future. Whether that look is cautious or bold depends principally upon the reviewer. This one prefers the cautious approach, believing that prophecy should be confined to a discussion of discernible trends or to demonstrated needs.

The outstanding fact in the realm of metals at the end of 1951 is the realization that we in America have much less of the metals essential for our present mode of existence than we had assumed. The reasons for this are simple: First, there are more of us with the money to pay for more things —that is, we have an ever-increasing civilian demand; second, we are supporting a large expansion in our military equipment program for both ourselves and our allies. We have chosen to supply these civilian and military demands simultaneously; to use a phrase, we wish to have both guns and butter. Since this situation bids fair to be with us for some time, we must ask: "What can we do about it?"

First, and most obviously, we can increase our raw material supply. This approach is not new; the process has of necessity been going on ever since the dawn of the machine age. One method of doing this is to mine more rapidly the known mineral deposits. This robs the future to pay the present because it adds nothing to our potential supply. Another and better method is the exploitation of newly discovered deposits such as the iron ore of Venezuela and Labrador, and the vanadium-uranium mines in the Colorado plateau. While this has certain aspects of the alternative first mentioned, it does increase our potential for many years, but unfortunately depends on the unpredictable chances of prospecting and discovery. A third and much more enduring method is the use of improved technology to work profitably those known deposits previously too lean for commercial use. All of our present domestic copper depends on such an accomplishment; lead and zinc supplies are greatly expanded by advanced metallurgy; even in the matter of iron ore we are about to witness the final stages of development of concentration and agglomeration of taconite —a revolution in the iron mining business that could easily add to our supply more iron ore than we have used to date. This third approach not only helps out in our present need but is also an investment in the future because it increases our potential supply. A fourth method is to control political and diplomatic developments so as to provide increased commercial access to foreign deposits. All of our tin, chromium, nickel, and natural rubber, and most of our supply of manganese and tungsten, are examples of materials thus controlled, but this approach is hardly within the province of the technical man.

These methods are not, however, the only ones available. Of at least equal and perhaps even greater importance is the method of utilizing more effectively our current supplies. In this way we not only conserve what we have at present; we also conserve what may be made available to us in the future. The method of attack is not new but it does need emphasis now. Our ever-increasing array of tools and our increased understanding of the required techniques make its promise bright, indeed.

We have for a long time been expanding our knowledge of the effect of minor but judicious amounts of incidental or deliberately added alloying elements on the properties and characteristics of the basic metal. In ancient times the discovery of the effect of tin or zinc when added to copper was of major importance. More recently (a century ago), we discovered the effect of small amounts of manganese on the rolling of the newly developed bessemer steel. Even today

we do not know how to roll, commercially, steel that does not contain a minimum amount of manganese. In view of the precariousness of our manganese supply, which has been with us since the outbreak of World War I, this is a worthy problem for our best researchers. Let us hope that it will receive more than casual attention from the American steel industry, for it is in all likelihood a problem that must be solved by numerous modifications in present iron and steel manufacturing processes rather than by such laboratory findings as that ziconium or titanium — metals even rarer or more costly than manganese — may be a partial substitute.

Perfection of accurate analytical procedures in the latter half of the last century gave us the basic tool needed for a systematic study of the effect of much smaller quantities of an incidental or an added element. The first studies were confined largely to finding what elements *to keep out* — that is to say, to the improvement of methods of refining. The same methods, plus modern physical testing techniques, were later to tell us what elements *to add* and gave us dependable zinc-base die castings, beryllium-copper alloys, lead-base cable sheath alloys, numerous special electrical alloys, and our present aluminum-base and magnesium-base alloys (to name only a few). Future application of the even more searching spectrograph and radioactive tracer elements will increase the tempo of such metallurgical advances. Furthermore, dozens of the rare metals have not even been tried as alloying elements.

In the field of constructional steel, we have already reaped substantial benefits from this approach. The current phase began with the study of the effect of aluminum additions to molten steel, the results of which are used wherever steel is heat treated or deep drawn. Next, under the pressure for conservation in World War II, hardenability was put on a quantitative basis by a close study of the true effect of relatively small amounts of the common alloying elements. Fortunately, the necessary groundwork had been laid by the researches of Bain, Grossmann, Jominy and Boegehold (all honored past-presidents of the ⊕) — fortunately, indeed, because it is probable that without this basic work we could not have stretched our alloy supply to cover the vital needs of the last decade. Many of the low-alloy compositions thus developed have now become standard steels; what started out to be a conservation measure in war has developed into a permanent part of peacetime economy.

We metallurgists have come to recognize that so far as heat treated constructional steels are concerned, all have substantially the same physical properties if they are quenched to martensite and then drawn back to the same hardness during tempering. Since we now know the quantitative effect of the alloying elements, we can specify within narrow limits the amount needed to harden a certain size section. In this respect, and within limits, the commonly used alloys are largely interchangeable. Advantage has been taken of this fact in working out substitutes for the early compositions, rich in alloy, in our present need for further conservation. It may not be inferred, however, that the alloying elements are each without its own specific effect. It is still true, for example, that molybdenum is most effective in reducing temper brittleness, that nickel is effective in reducing notch sensitivity at low temperatures, and that chromium promotes the formation of massive carbides in high-carbon steels or in carburized steels. We now have evidence that the minimum amount of a particular alloy required to achieve its specific effect is sometimes dependent upon the combination of alloys present. We may not, therefore, conclude that all alloys are alike in all their effects, even though they have a certain degree of interchangeability.

Quantitative hardenability has another important economic aspect. Since we specify many of our steels by hardenability as well as alloy type., we find we can relax chemical specifications which were becoming uncomfortably restricted. The hardenability test is an integrator — it measures the over-all effect of all of the factors. Thus we can accept wider limits for any of the significant elements because the hardenability test tells us what the behavior will be, regardless of variation in composition. By this method many a heat of steel can be accepted and used with assurance which would otherwise have been diverted and therefore unavailable for a critical application.

Now we have boron to add to our list of

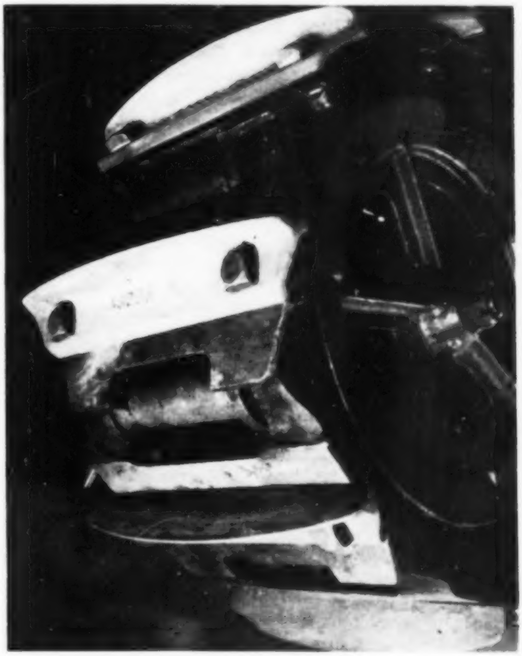
alloying elements for steel. The development started before World War II but it remained for the pressure of the present emergency to bring results. Used in incredibly small amounts — an ounce per ton is enough — it represents the ultimate to date in the judicious use of small amounts of alloy. Its exceptionally powerful effect on hardenability has been well established. Metallurgists in the producing and consuming industries are now joining efforts to determine the alloy combinations, including carbon, wherein it delivers the most advantageous results. It has already been demonstrated that boron can replace part of our critical alloys; for that reason alone, it will be of great value in the immediate future, even if it is still too early to tell if it will achieve a permanent place in our list of alloying elements.

This truly spectacular action of boron has a certain reflection in the crystal ball. What of the future? Metallurgists know a good deal about the action of perhaps a dozen elements, alone or in combination, on the properties of steel. But there are 80 other elements, metallic, semimetallic, and nonmetallic, about which they know practically nothing. Some day a Moses will appear to lead them through this wilderness; if he is wise in the ways of science there is the prospect of discoveries beyond all the treasure of the Promised Land.

In the field of high-temperature alloys, we are not nearly so well advanced as in the engineering steels. Although we have succeeded in producing alloys which deliver satisfactory service at reasonable cost in most land-based equipment (even here, demands for higher temperatures and pressures are pushing present materials very hard), we are still short of the mark in the field of gas turbines. This is particularly true of lightweight (aircraft) turbines which, while of paramount interest now for military use, will shortly be of civilian use. We have succeeded in making alloys that are reasonably adequate for present designs, but the designers are even now asking for higher operating temperatures for more efficiency. Longer life is required, too. For want of fundamental knowledge of what actually provides the necessary characteristics in materials for this service, we are repeating our traditional prodigality in the use of scarce alloy; in this case most of it eventually becomes nonrecoverable military scrap. What is needed is some truly fundamental thinking, such as Merica and others did for precipitation hardening of aluminum, and Bain and others did for austenitic transformation in steel. Until such basic concepts have appeared and been proven, we must continue on the present inadequate basis. Here is another problem worthy of research's best effort.

We are, however, making a mistake if we assume that these problems of materials are the province of the metallurgist alone. The designing engineer, too, must do his share in extending the coverage of our present supply. This is not only true for the short-term view, but also for the long-term view which, if our present economy is to prevail, requires more and better products at less relative cost. In the field of aircraft power plants, the designer has gone a long way (witness the very favorable weight-horsepower ratio); but so far as high-temperature applications are concerned, since we admittedly do not now have the

Photo by Henry M. Mayer



necessary answers metallurgically, can we not use a more favorable design?

In other fields of design the answer to the question is "Yes". It *is* possible to improve and conserve by applying ideas we already have — plus some hard work. The days are long since gone when the accepted method of removing the cause of failure was to make the part heavier, that is, to decrease its flexibility and thus lower the stresses. The advent of automotive equipment with its dynamic stresses and its weight limitations quickly proved the fallacy of this idea. Next, and quite logically, came the idea of increasing the strength of the part by using stronger material. For steel parts, this often meant heat treatment and with it came a new and much wider field for the metallurgist. But stronger, heat treated steel, helpful as it was, did not provide the complete answer, as was discovered when we began to study stress distribution and the factors which control it.

The ideal machine, from the standpoint of maximum utilization of materials, was described many years ago in nontechnical terms by Oliver Wendell Holmes in "The Deacon's Masterpiece", better known as "The One-Hoss Shay". It will be remembered that the deacon built a buggy without one weakest spot and it lasted 100 years, but

"You see, of course, if you're not a dunce
How it went to pieces all at once,
All at once and nothing first,
Just as bubbles do when they burst.
End of the wonderful one-hoss shay,
Logic is logic. That's all I say."

What he said in those delightful verses can be translated into engineering jargon by saying that the ultimate in design can be achieved by selecting the section modulus of each part so it is stressed exactly the same in relation to its endurance as is every other part. To achieve this we must study stress distribution closely — not only the calculated stress — which, because of the complexity of the problem, often cannot be more than a first approximation — but also the operating stresses imposed by service. This includes such hard-to-predict and hard-to-measure factors as momentary overloads, reversals of stress, residual stresses and temperature effects. Such a program involves much testing and development. The degree to which it is carried must be governed by the probable return; not all manufactured products can carry the same development burden but the trend is distinctly toward increased emphasis on such testing.

In one of his vivacious and informative talks Frank Tatnall said in four words how to think about such things: "Stress flows like water." The effect of poor fillets, undercuts, notches, sudden changes of section and the like, are now known, but engineers still violate the fundamentals every day in new designs. The more they visualize beforehand the stress pattern in a part, the better the actual part will be. It has often been shown that, properly designed, a more serviceable thing is actually lighter than its predecessor because it is proportioned in accordance with the imposed stresses. When, as often happens, designers cannot visualize them at the drawing board, the stresses can be measured in test, using the many tools now available.

In our efforts to do more with less, we must have research and more research and then more research. Americans so far have made many technological advances by developing fundamental ideas conceived by others; atomic fission is a good example. Two world wars destroyed or made sterile many of these foreign sources with the result that we are now largely dependent on our own efforts. Our record indicates that Americans continue to do well with "applied" research; there is ample proof that Americans can do "pure" research. The question is: "Can we do enough of it?"

Since pure research consists essentially of probing into the unknown, it requires a particular type of mind and training. The laws of probability tell us that we should have our share of such minds; the task, therefore, becomes that of finding and developing them. We now have more people taking advanced work in American colleges and universities than ever before, which augurs well for the future supply of researchers. But it is fair to ask: "Have they been well selected? How many worthy ones remain undiscovered?" We must continue our efforts to develop a screening process that cuts to a minimum our waste of our most valuable asset, the original thinker.

The old recipe for rabbit pie says: "First, catch the rabbit!" In research we can prescribe with equal acumen: "First, get an original idea!"

By B. Karnisky, Head, Welding Research Section, Research and Development
Pullman-Standard Car Mfg. Co., Hammond, Ind.

Progress in the Welding Industry

THE WELDING EQUIPMENT INDUSTRY continues to grow by leaps and bounds — nearly twice as fast as industry in general. According to *The Welding Engineer*, production of arc welding electrodes in 1950 exceeded 420,000,000 lb., more than double that of 1940. Arc welding sales in 1950, including electrodes, equipment and supplies, totaled nearly $87,000,000; gas welding and cutting equipment and supplies over $281,000,000, and resistance welding over $24,000,000. Total sales for the welding industry in 1950 exceeded $392,000,000. These figures are large. More impressive is the rate at which they are growing.

Therefore, it is well to inquire whether the welding industry has grown so fast that technological improvements have not kept pace. Let us review some of the highlights of the past in order to make an accounting.

You may recall the rapid conversion to welding in production after its acceptance by a few pioneering manufacturers. Many changed from riveted or cast steel structures without any change in design except to accommodate the welds, and with very little consideration of the materials involved. The structure's strength was assumed to be sufficient because the steel in the new design was of the same size and strength, and it was the duty of the welding engineer to apply sufficient weld to hold it together.

RESIDUAL STRESSES

The engineer, during these years, needed to have a sense of judgment which would enable him to select the most productive welding procedures, fixtures and processes. There had been much experience with shrinkage and distortion, so weldments were stress relieved — if only to maintain accurate dimensions during machining. Obviously, these weldments contained residual stresses which might be harmful, so, as a safety measure, items which would receive critical loads in service were also stress relieved. Enormous furnaces were constructed for the heat treatment of large chemical and petroleum refinery vessels, but even these were not large enough for the materials used in ships and bridges which later gave so much trouble.

At this date, we realize that residual stresses approaching the yield strength of the material are usually present in the weldment. It is now generally conceded that these high stresses redistribute themselves without any deleterious effect after the structure is placed in service, if the metal at and alongside the weld is sufficiently ductile and if it is free to move — not constrained by other forces. However, we do not know what occurs at the locations of high residual stress during high-velocity or impact loads which may not give sufficient time for redistributing the stresses.

WELDABILITY

Meanwhile, many fabrication difficulties were encountered involving steel defects and cracks in the welds or heat affected zones. In order to assure quality, welds were magnafluxed and even X-rayed. Peening of the weld deposit helped to prevent cracks; in extreme cases a 25-20 Cr-Ni electrode was used because of its ductility. The metallurgist was called upon to determine which steels were weldable without cracking. Many tests were developed, and some manufacturers use them to classify the relative weldability of commercial steels.

Through knowledge of austenite transformation rates, preheating temperatures were selected to control the cooling rate of welds and thereby prevent formation of brittle martensite in the heat affected zone. It was discovered that microcracks are due to the precipitation of dissolved hydrogen gas during the low-temperature austenite-to-martensite transformation in the heat affected zone. From this knowledge, the low-hydrogen electrode was developed in which all the ingredients that might produce hydrogen, including moisture, were eliminated from

the coating. With such an electrode many of the "problem steels" may be welded without preheating, weld cracks in high-sulphur steels are eliminated, and the low-temperature impact properties of the weld deposit are improved.

In spite of a large amount of study, there is still no simple test for weldability of steels and for the most efficient peening procedure. (The effects of over-peening are yet to be determined.) Latest research indicates that welds made with commonly used electrodes may contain microcracks if cooled rapidly through 400° F. In other words, many welds made at low temperature may contain these weakening fissures. Hydrogen again appears to be responsible, since the low-hydrogen electrode is crack-free after similar usage. In view of the remarkable success of the low-hydrogen electrode coating, perhaps a similar flux should be developed for submerged arc welding. This is a problem for the immediate future.

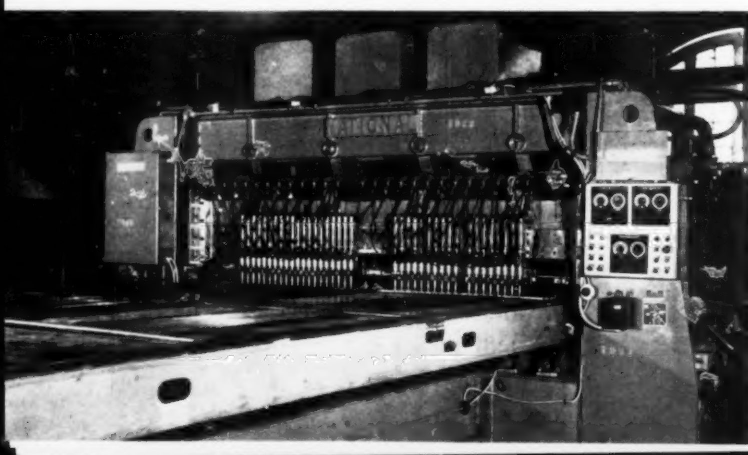
MATERIAL SUBSTITUTIONS

Ordinary structural steel commonly used for welding was usually limited to about 0.23% carbon for shop welding under all conditions, although higher carbon steels could be welded with special precautions. In the hot rolled condition, this steel provided a minimum yield strength of 25,000 psi. and a minimum tensile strength of 50,000 psi. Immediately after the introduction of the low-alloy, high-strength steels having a minimum hot rolled yield strength of about 50,000 psi., new designs for lightweight construction appeared. These new steels proved to be readily weldable except for a few instances where rapid cooling produced a brittle weld. (For example, in butt welding sheets by submerged arc, the groove in the copper back-up had to be opened in order to reduce the drastic chilling of the weld.) The shear strength of spot welds in these steels was satisfactory, but the normal tensile strength was low because of the lack of ductility—a matter which was improved by an electronic control which introduced a second impulse at a lower current after the weld was completed, putting in enough heat to temper the weld nugget and reduce its hardness.

Stainless Steels for Structural Members—Faying surfaces of spot welded joints in mild or low-alloy steels are difficult to protect from corrosion, in spite of the many sealers which are on the market, so designers have turned to stainless steel for structural members. Of course, there is the problem of carbide precipitation with subsequent corrosion, but by limiting the amount of heat during spot welding, no harmful carbide precipitation occurred at the exposed surfaces. Extra low carbon stainless, as well as stabilization with columbium or titanium, further minimized harmful carbide precipitation during welding.

Where only atmospheric corrosion is involved, Type 301 (17-7 Cr-Ni) may be the most economical stainless steel to use in welded structures. To take advantage of the high yield and tensile strengths available in cold worked material, it is necessary to determine the economics of the problem—whether to use thin, high-strength material with adequate flanges and gussets to develop the joint efficiency, or to use heavier sections of the material less drastically worked and of lower strength. The first type of joint has low ductility, while the latter is extremely ductile and even after arc welding will have a yield strength greater than the low-alloy high-strength steels. Some fabricators have made many tests (static, impact and fatigue) of small specimens and full-scale joints to determine the strength and safety of these designs, but this type of information is [illegible]

Pullman-Standard Machine Welds Any Number of Spots up to 48 at a Single Stop of Work Table



generally disclosed. Small test specimens do not give this information because changes in section or weld notches in the structure may concentrate the working stresses at the heat affected zone where the cold rolled strength of the stainless steel has been reduced.

In many instances it is economical to substitute mild or low-alloy steels for a portion of the stainless steel in such structures. These dissimilar metals are usually welded with 25-20 Cr-Ni electrodes to take care of dilution, even though such fully austenitic welds are susceptible to hot cracking. Some brilliant metallurgical work disclosed the influence of silicon in forming weak intergranular films in the austenite. Cracking is now eliminated by balancing the carbon with the alloy content and reducing the silicon, or by selecting a composition having a partially ferritic structure. In a particular instance, a submerged arc butt weld joining an 18-8 stainless and a low-alloy steel is made satisfactorily with 29-9 Cr-Ni welding wire and adding molybdenum to the flux. Successful spot welds between these two materials were made by selecting electrode shapes and pulsing current which fuses the interface without mixing the dissimilar metals so as to form a brittle nugget.

One problem with us now is caused by the restriction of the use of nickel. What can industry use in place of 18-8? The 16 to 18% chromium-irons may be a satisfactory substitute if they can be welded with 25-20 Cr-Ni electrodes (followed by stress relief). However, welds in high chromium-irons are coarse grained. The heat affected zone cannot be refined by heat treatment, and coarse crystalline metals are questionable in structures loaded in fatigue.

The stainless steels are readily welded by many processes. Fabrication of heavy machine parts was aided by the discovery of the flux or metal powder injection cutting processes, in which these powders are injected into the kerf while flame cutting to remove the refractory oxides. The inert-gas-shielded tungsten arc is well adapted for thin material which can be flanged or upset, and the edges merely fused. If metal must be added to the joint a consumable electrode may be fed automatically through the nozzle of the welding gun and shielded with inert gas (nitrogen, argon or helium). Since relatively high current densities are used, welding is at a rapid rate; likewise the weld zone cools rapidly, and consequently there is a minimum loss in physical properties induced by prior cold working. Gas shielded arc is therefore an efficient production tool and preliminary studies indicate that it will be suitable for all materials commonly arc welded, including titanium. Currently, mixtures of gases are being tested to stabilize the arc and increase the efficiency.

STRUCTURAL ALUMINUM

Structural aluminum for replacing steel presents the welding designer with problems very similar to the above, involving stainless steel. In order to make the substitution as economical as possible, the high-strength heat treated grades such as 61S-T6 should be used. However, the annealed or overaged zone adjacent to a butt weld reduces the joint efficiency to about 60% of the parent metal's strength.

Cold worked 2S, 3S and 4S grades are usually welded with 2S filler metal of 5000-psi. yield and 13,000-psi. tensile strength; heat treated alloys are usually welded with the 5% silicon alloy, 43S, of 9000-psi. yield strength and 19,000-psi. tensile strength; considerable alloying of the filler and plate materials occurs and the strength is increased accordingly.

Fillet welds in aluminum are not as strong as butt welds because of stress concentration at the joint. Therefore, each new welded structural design in aluminum must be tested individually to determine the efficiency of the joints in the same manner as previously described for stainless steels.

Aluminum is widely used in many applications; the welding methods used in these applications have advanced tremendously. Methods for measuring the contact resistance of aluminum after cleaning have improved the consistency of the spot welds. "Slope control" for single-phase welders also has done much to better the quality of spot welds, particularly in aluminum; a gradual increase in current at the beginning is provided by the slope control, reducing the expulsion of metal and electrode maintenance. Aluminum alloys may now be flash welded, and this process will be rapidly developed in the next few years. Flash welding machines are now available with a dual pressure-upset arrangement — a low

force and high current, followed by a heavy forging pressure — and with precise alignment. The loss in physical properties is minimized by making a very narrow weld and heat affected zone.

Cold pressure welding of aluminum has aroused considerable interest in the popular and trade press, but the large amount of deformation required to make the bond — over 50% of the joint thickness — would probably reduce the fatigue strength considerably. Therefore, the process does not appear to be applicable to structural welding, although it may be entirely satisfactory for the spot or seam welding of containers. At elevated temperatures, the pressures required for diffusion are considerably lower; perhaps pressure welds made in aluminum at about 600° F. will eliminate some of the disadvantages of cold welding.

Fatigue strength of spot welds in aluminum has been raised by pressing the cold surface of the completed weld — a variety of peening. Further advances may come about from a method reported from Germany; tests there show that when ultrasonic waves are applied to the spot welding electrode the coarse cast structure of the weld nugget is refined and the shear strength improved tremendously. Another interesting application of high-frequency impulses is an ultrasonic soldering iron, used without flux, which removes the oxide film from aluminum by high-frequency vibrations. It would seem that ultrasonic treatment could be used, in the future, to improve the soundness and strength of arc welds in aluminum.

BRITTLE FRACTURES

Possibly no single problem has so disconcerted the welding industry as the brittle fracture of certain important welded structures. Fractures in welded ships during the past war, and the more recent fractures of a large ship and a bridge in Canada, are examples. Cleavage, or brittle fracture, occurs suddenly when a certain load level is reached, progresses almost instantaneously with very little deformation or energy absorption, and results in extensive damage. Although such disastrous failures are still comparatively rare, they should never occur, barring an overwhelming catastrophe of unforeseeable nature.

There are numerous factors involved in the initiation of a brittle fracture, so its prevention is a complicated and abstruse problem. In general, the material, its temperature, the rate of loading, notch geometry, and degree of restraint are directly involved. The "transition" temperature, which is a measure of the ductility of the metal, is raised by carbon, phosphorus and vanadium in steel, and lowered by nickel, manganese, low finishing temperature in the steel mill, and fine grain size. Steelmaking practice also comes into the picture, for a killed steel is much more satisfactory in this respect than a semikilled steel. The notch geometry, or stress concentration, may increase the strain rate enormously, and force the metal to elongate (strain) locally at very high rates.

In many instances, fractures of all-welded structures* can be eliminated by a change in design which introduces flexibility or energy absorption capacity, and by relocating the design notches or fabrication notches where stresses are low. A welded design should not copy the riveted design, but instead the material should be distributed into locations where it is most needed, with generous radii instead of sharp corners, and a smooth streamlined appearance overall. An optimum welded design necessitates a compromise between flexibility and satisfactory fatigue properties.

The designer needs basic information on the behavior of steels in the plastic range, since many structures — particularly high-temperature equipment — are designed for use in this range. The yield strength of steel increases with rapid strain rates, but the effect of low temperatures and repetitive loading in this range is not generally known. Here is a fruitful ground for future research.

The mild steels are usually joined with weld metal with a considerably higher yield strength than the parent metal. It is almost traditional that the weld should and can easily be stronger than the metal joined. However, when such welds are placed parallel to a tension load, the base material may yield plastically and force the weld to carry

*Editor's Footnote — Maybe a new word should be coined to connote structures without slip joints. Suggestions will be welcomed. The common word "monolithic" is not too good, for it means "of stone, without joints". "Monometallic" might do. "Unipartous" is possible. "Jointless" won't do, because an all-welded structure certainly has joints.

the load. Under these conditions, any defect or notch in the weld, such as the termination of a fillet weld, could be a focal point for a cleavage failure. This would indicate a need for an electrode with physical properties comparable to those of mild steel.

HIGH-SPEED PRODUCTION WELDING

Ever-increasing labor rates in the fabrication shop create a tremendous demand for welding processes of higher speeds. In no other field, at present, can research pay for itself so quickly.

The instability of the welding arc itself, stray magnetic fields, and the reactance of the material in the electrical field, all adversely affect the ability to weld at high speeds. Studies of metal transfer across the arc have led to a few electrical and chemical methods for increasing the stability during welding. High current densities or high-frequency currents are examples of the electrical methods. Chemical methods include the use of thoriated tungsten electrodes for inert-gas-shielded arc welding, and the addition of fluorides to arc welding fluxes. Major improvements in the stability of the arc appear to depend on the future development of new fluxes.

In some instances the speed of submerged arc welding has been more than doubled by the use of tandem machines, such as a combination of one alternating current and one direct current machine, or two direct current machines. The two arcs operate in a common molten pool and are quite stable.

Development of large portable spot welding machines has increased the use and adaptability of resistance welding. Large flash welding machines increase production of special items. Mash seam resistance welding (where the sheet edges are lapped slightly and then mashed and fused simultaneously) offers extremely high production speeds. One distinct advantage of this process is that there are no lap joints to require corrosion protection.

Flame pressure welding appears to be one answer to the difficult problem of welding hardenable steels. In this method the saw cut edges are abutted; gas heat and pressure are then applied until diffusion, coalescence and grain growth occur across the boundary. The region is then flame normalized, if necessary.

Stud welding is another process which has assisted fabrication immensely. A recent adaptation utilizes condenser-stored energy to produce an arc between the tip of the stud and the work, first to ionize and remove the metal scale, and then progressively weld the stud into place. No flux is necessary; nonferrous or ferrous materials may be joined.

CONCLUSION

There is a considerable lack of basic design data which will insure that fatigue or brittle fracture failures would not occur in all-welded structures. The steel industry must share the responsibility of the designer by producing and recommending steels which will be satisfactory for the service conditions involved. That steel quality is an important factor is indicated by the fact that weldments made in England, of English steel relatively high in manganese, were much less troubled with brittle fracture.

Regarding fabrication processes in the future — much depends upon the structural designs which evolve. If designs are to be streamlined, with material used economically and distributed according to where it is needed, with generous radii to minimize stress concentrations — then the material will be formed to shapes in large sections in order to keep welding to a minimum. Large presses, limited only by the size of steel plate or sheet available, will form integral stiffener or load-carrying members. Flash welding and other completely automatic processes will be used more for joining the large sections.

A basic problem in welding, in common with the foundry industry, is the removal of hydrogen, nitrogen and oxygen from molten metal, and the refinement of the coarse dendritic structure of cast metal. The ensuing improvement of physical properties, particularly the ductility of welds, would expand the use of some materials.

The technological advancements in the welding industry have been tremendous during the last few years, particularly in the metallurgical phases of welding and the development of welding processes. This pace should continue in the future, along with the simultaneous improvement of structural materials. The need for sound metallurgy is obvious and pressing.

By F. G. Tatnall, Manager of Testing Research, Baldwin-Lima-Hamilton Corp., Philadelphia

Testing Today and Tomorrow

What do we have, and what do we need in testing? That is the question posed by The Editor in asking for this review.

Testing is an expanding activity which needs a continuing supply of new devices to work with. Lately, the situation regarding testing devices takes a turn which reverses the usual order. Thus — the conventional beam-and-poise universal testing machine of the last generation was adapted directly from the mechanical scale; today the process is exactly reversed. The newest thing in electronic scales has developed from devices primarily created for the purpose of testing.

It might be interesting to follow the course of applications of electronics in testing equipment and to try to forecast how such devices might help attain future needs.

It began with the use of the linear differential transformer shown in Fig. 1. This is actually a tiny transformer with a moving core whose output voltage varies with the displacement of the core from null position. This was applied in extensometers and stress-strain recorders to gain many important advantages; later extended to load indication in hydraulic testing machines, it finally entered devices which print values for yield strength and "extension-under-load".

With its help, families of stress-strain curves could be recorded rapidly and with precision on a single chart. This was a boon to routine acceptance testing, because such record could serve as a very revealing test report. It enabled testing engineers to control the rate of straining, needed to augment the existing rate-of-loading control which had long since been familiar equipment on hydraulic testing machines.

Electronics broadened the usefulness of the screw-driven testing machine when speeds of motors for driving the screws could be steplessly varied over a wide range by a thyratron tube. (The tube acted as a valve, speed being changed by a potentiometer.) What is needed next in electronic motor control is program control (now done on hydraulic machines) where approach to yield point is at a fast speed, automatically changing at a predetermined point to a slower specified speed in order to pass through the yield range, then automatically stepping up again to fast speed to fracture — all of which saves time without introducing misleading values for yield point.

Another development in testing machines was the application of bonded wire strain gages of "postage stamp size", in a tension-compression load cell, Fig. 3. These elements find use in torque meters, speed and torsion vibration pickups, differential pressure cells and shear devices. Figure 4 shows a crane scale in which the load cell is built into a link between crane hook and lifting magnet. Similarly, track scales can be mounted on rugged cells, thus giving a weighing device with no moving parts like lever arms or linkages. Recently a ladle car was equipped with load cells under both trunnions. Many other industrial applications are possible.

The wire gage, heart of the load cell, has worked as a versatile extensometer (Fig. 2) for stress-strain recording, printing and speed control. High speed of response is a characteristic of this device; full sized stress-strain curves can be recorded at impact speeds; completely reversed load cycles and other unusual combinations can be handled. What is needed next is high-speed printing of test values.

We pause here to note that the bonded wire strain gage was born in the pendulum impact machine. It was first reported in the A.S.T.M.'s Impact Symposium in 1938 ("Stress-Strain Relations Under Tension Impact Loading", by Clark and Dätwyler) and has since been used with an oscilloscope screen, notably at Watertown Arsenal, for indicating stress-strain curves on notched bars in a pendulum impact machine. In determining the transition temperature (that temperature at which ductile materials become brittle) the strain gage is widely used on centrally notched plates in the form of a clip gage. This device transforms axial deformation into bending, thus gaining increased sensitivity. The wire strain gages have also been used successfully in torsion

impact and even in testing impact of projectiles, for as yet no upper limit to their frequency response has been found.

As long as we are on the topic of impact testing, it may be mentioned that a future need is a thoroughly reliable notched bar impact test as a measure of notch sensitivity —one which does not vary from machine to machine; one which is not sensitive to slight variations in testing technique. (This has plagued the suppliers of gun forgings who must meet a Charpy bar specification at minus 40° F.*) The direct explosion test has points of interest (see a paper by G. S. Mikhalapov in A.S.T.M. Bulletin No. 172, February 1951) and the bonded wire gage lends itself to measurements in such test.

CREEP, RUPTURE, AND FATIGUE

Creep and rupture testing need help because of the increasing importance of turbojet engines and oil refinery equipment. The main thing needed here is a high-temperature strain gage, stable in static tests for 1000 hr. at 1600° F. Such a gage could be bonded to the creep specimen on its reduced section and could automatically plot the strain-time curve. As is true of endurance testing, creep data require such long drawn-out programs that stress-rupture experiments (apparently giving data which plot as straight lines on log-log coordinates and consequently can be extrapolated short distances with reasonable certainty) are in favor with metallurgists and designers working with high-temperature equipment. What is needed is a short test for acceptance purposes, so dangerous off-heats can be scrapped.†

In the fatigue testing of thin sheets like cartridge brass, which are difficult to test in any other way than in bending, two bonded wire gages on the specimen control by feedback into a magnetic oscillator, and at the same time register maximum stress on an oscilloscope screen. Again, wire gages on a dynamometer in series with a specimen subjected by a mechanical oscillator (a rotating unbalanced weight) to either alternating tension, flexure or torsion maintain the speed of the oscillator near resonance by acting upon the drive motor through the "Thy-mo-trol" speed control and also keep a running record of forces developed. In the near future we will need mechanical oscillators for higher speeds.

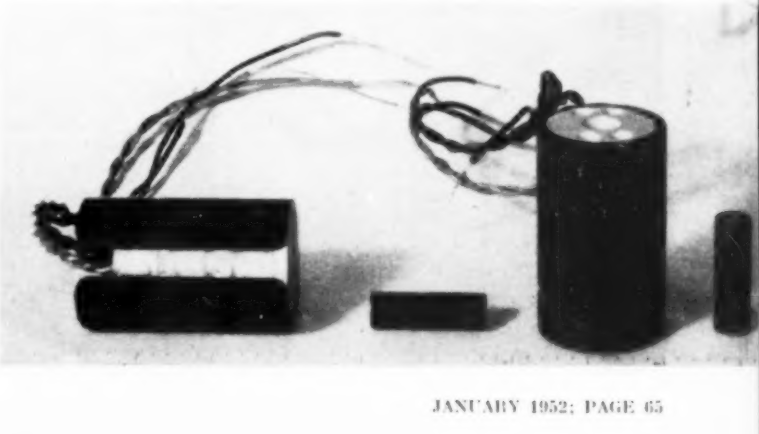
The resonant electronic oscillator or "loud-speaker" type of mechanism for inducting alternating loads is widely used to test specimens or complete parts and assemblies in fatigue. A simple form of such bend-test machine is a tuning fork where the oscillator acts upon one tine of the fork (in the form of an inverted "U") at resonant frequencies, and the test specimen forms the connection between the two tines of the fork.

In the push-pull machine for fatigue testing under axial loads, operating either by mechanical or hydraulic power, wire gage loop dynamometers or differential transformer dynamometers in series with the specimen maintain constant conditions. Corrosion fatigue tests or hot tests can be

*The variation, laboratory to laboratory and machine to machine, in test results on 4340 bars, uniformly quenched and tempered, is adequately set forth in an article in *Metal Progress* last month (p. 69).

†In a paper prepared for the World Metallurgical Congress and printed in *Metal Progress* for November 1951, Messrs. Delbart and Ravery advance the idea that metals meeting a given chemical specification can be arranged in order of excellence by determining the stress for creep of 1.0×10^{-4}% per hr. at 30 hr. which (for the alloy steel they investigated) is about the same order as found when the test is extended to determine the stress for 0.1×10^{-4}% per hr. at 1000 hr. They suggest that the 30-hr. test may be used for acceptance.

Fig. 1 — Differential Transformers Whose Electrical Output Varies With Position of Movable Core. Natural size



Nondestructive Tests

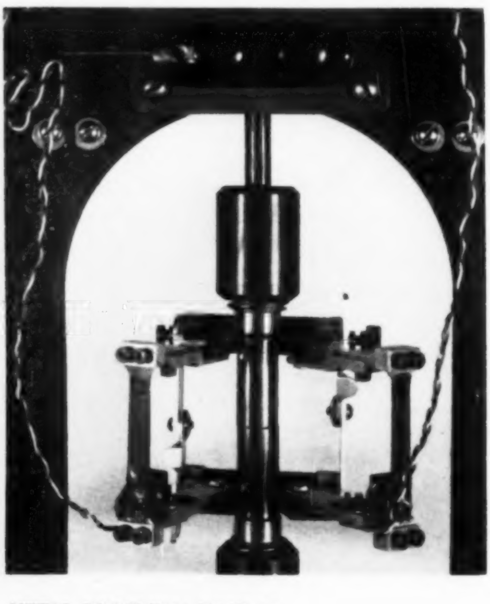
made in such fatigue machines by surrounding the specimen with either a fluid-filled chamber or a wire-wound muffle.

We need a reliable electronic tester for measuring damping capacity.

We also need badly an accelerated fatigue test which will indicate endurance limit without going through the slow, painstaking series now required. An interesting approach has just been announced by Professors Rosenholtz and Smith of Rensselaer Polytechnic Institute. News releases indicate that they have found that the coefficient of expansion, 20 to 100° C., is a minimum for samples at the threshold of damage. Preliminary treating of each test piece involves stressing in tension and then a run of 100,000 cycles of stress. The tensile stress is different for each sample, the series straddling the expected endurance limit. Each prestressed sample is then given the same 100,000-cycle run.

Nondestructive testing is in the spotlight, and leans heavily on the electrical approach. For brevity, the discussion must be sharply condensed. Fortunately the reader can examine an 80-page compilation

Fig. 2 — Recording of Stress-Strain Curves at Impact Speeds Is Made Possible by Extensometer Equipped With Wire Strain Gages. Gages are bonded to vertical strips in foreground



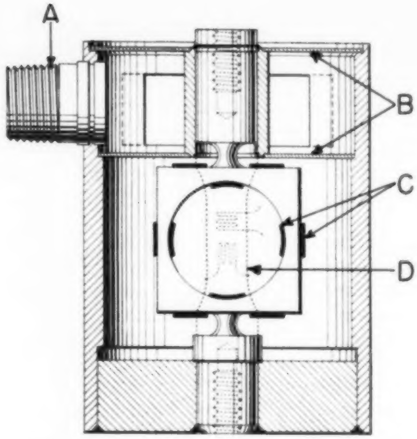


Fig. 3 — SR-4 Universal Load Cell. (A) Cable fitting, (B) flex plates, (C) loop with gages for low-capacity cells, (D) strut with gages (dotted grids) for high-capacity cells

by McMaster and Wenk of Battelle Memorial Institute in A.S.T.M. Technical Publication No. 112 entitled "A Basic Guide for Management's Choice of Non-Destructive Tests". It classifies 12 basic test methods, described in more than 250 patents and 500 technical papers, as follows:

1. Electric current conduction
2. Electromagnetic induction
3. Magnetic field
4. Electric field
5. Thermal
6. Penetrating radiation
7. Mechanical vibration
8. Luminous energy
9. Pressure, leak, and penetrant
10. Mechanical caliper or gage
11. Chemical spot
12. Tribo-electric

The features of each method are tabulated in this roundup, and information is organized to assist in selecting the test.

What we need next is a nondestructive means for measuring residual stress (or internal stress) which will not require us to drill or cut slices out of the part — a technique which is now the basis of residual stress analysis with bonded wire gages.

We also need a better means of inspecting welds. Perhaps a low-priced baby Betatron may be in the cards for routine work. At least, the three-dimensional stereoscopic viewing of X-ray photographs could be more widely used.

A most important branch of testing which is engaged in finding out why the material in a structure in service does not

behave like a specimen of the same material in the laboratory calls for the testing of parts, components and assemblies. Static tests of the part measure the stress level throughout and attempt to determine if all parts of an assembly are taking their share of the applied loads. Dynamic tests follow to study life expectancy and to find if the previously determined stress level is safe under expected service conditions. The shape of the part fixes its stress distribution, and the material from which it is made fixes its notch sensitivity.

In this task of estimating the reliability of a complicated part or structure we rely upon laboratory tests to determine the basic strengths of the materials. Static and dynamic tests of parts, components and assemblies show how these basic strengths are modified when the materials are used in a structure. We find that basic strength data are modified by numerous conditions as follows:

1. Stress concentrations brought about by the shape of the part.

2. Temperature has effect on strength and stiffness of materials, and creates strains due to temperature gradients. Low temperatures may also cause loss of ductility.

3. Multi-axial stresses which can cause loss of ductility through restraints.

4. Corrosion, which reduces tensile and fatigue strengths.

5. Impacts and occasional overloads which can reduce fatigue life, or change the stress pattern by permanent deformation.

6. Combined stresses (which can be cumulative).

7. Residual stresses, which can be harmful or beneficial, depending upon their location.

8. Dynamic stresses, which appear as crack-opening alternating loads, vibrations or resonant peaks.

In conclusion, it sometimes seems that improvements in testing devices and methods are coming so fast from so many directions that we should have a two-year holiday to organize our instrumental gains!

Fig. 4 — Electronic Crane Scale (White Link Below Hook)

By Arthur H. Allen, Technical-Business Consultant, Cleveland

INTEGRATION of heat treating equipment into the parts-production line, making it in fact a machine tool with built-in functions of loading, movement and discharge, is a trend which has accelerated rapidly in the postwar years. The onrushing defense program, combined with unrelenting pressures for cost reductions, suggests that many new lines of heat treating equipment, all but automatic, will appear in the years just ahead.

Mechanized Heat Treatment Points to New Goals in Costs and Quality

Induction processes naturally have led the way in this effort toward automatons, whether it be for hardening, heating, annealing or joining of metals. The established advantages include the ability to keep pace with the production line; reduced steel costs accruing from replacement of alloy with carbon steels; lower machining costs by machining before hardening; reduced distortion; and ability to harden selectively. It is also usually possible to fit induction equipment easily into the production line, perhaps locating the electrical generators overhead.

Adaptability and economy of one installation using radiofrequency heating is demonstrated by a case study showing how 432 different sizes of textile machinery rolls are hardened, with a reduction of 63% in direct labor costs and an increase of 145% in output over former furnace methods. Admittedly the first cost of induction equipment is high, and deliveries on generators, fixtures and auxiliaries are seriously delayed at the moment — so much so that some plants have turned to alternate processes such as flame hardening.

Ordnance production is fathering a number of new and versatile setups. One, for example, which went into production last year is an arrangement for induction hardening the concave bearing surfaces of the 80-in. rings comprising the ball bearing raceways for tank turrets. There are three rings in the assembly, each treated on a separate induction unit powered by a common generator. Rings are placed on an inclined rotating table, the induction head (with a curved, laminated shoe) is lowered to within 1/8 in. of the ring, and a pushbutton starts the cycle. The ring rotates slowly under the inductor, brought to temperature, and quenched immediately by coolant streaming from the trailing edge of the shoe. One ring is traversed in something like 4 min., which is a fraction of the time needed by a former flame hardening process. Hardened area and range is controlled closely at Rockwell C-58 to 60.

In several of the cartridge case programs now being tooled, annealed 1030 steel will be used. After the case is deep drawn, the lower end will be hardened to C-55 by the induction method.

Another noteworthy application of localized hardening incorporated directly into the production cycle is the installation of a coil-carrying mandrel, drilled for spraying quenching solution, on the last station of an eight-spindle automatic screw machine. Parts are small, cup-shaped wing bushings for automotive universal joints, formerly carburized locally at the base of the bore by first copper plating, then machining off the area to be hardened and finally running through a rotary-retort furnace for carburizing, quenching and tempering. Installed on the screw machine, the hardening coil advances to proper depth inside the bushing, heats the correct area and quenches it — all in time with the machining cycle.

CARBURIZING PROCESSES

In furnace treatments, gas carburizing continues to gain favor, particularly its modification identified widely as "carbonitriding" or "dry cyaniding". Possibly a better name for the method would be "cata-

lytic carburizing", if you agree with the theory that nascent nitrogen (formed from the ammonia mixed with the carburizing gas) alloys with the ferrite rather than forming nitrides and so lowering the upper critical temperature of the steel, thus permitting carbon to be absorbed more rapidly. The critical cooling rate is also lowered. One modification of the process introduces ammonia only toward the end of the cycle, the aim being to develop a higher hardness in the outer case.

This process seems to contradict the theory just mentioned, for maximum possible quench hardness due to carbon is reached at about 0.65% C; extra hardness at the very surface — if achieved — must be due to some other element. Existence of contradictory opinions as to the nature of the "carbonitriding" action, each based on a set of facts, suggests that the exact truth still eludes the theorists.

Particularly for the boron-treated steels, now coming into steadily wider use because of alloy shortages, does the carbonitriding process show merit. There the problem is to develop a sufficiently hard case without undue warping and distortion from excessive core hardenability. For best carburizing results the boron steels apparently should not exceed 0.90% carbon in the case.

Distortion has proved the major drawback in much of the early work on carburizing the boron steels, especially in gears. Obvious remedial steps are to quench at a higher temperature, possibly in salt, or to quench from a lower temperature. Since carbonitriding is done at a lower temperature (1450 to 1600°F.) than conventional carburizing, this is of some benefit. Quenching on a spud or other special fixture tends to restrain distortion, but is expensive in labor. Further, some shifts have been reported from 94B20 boron steel, first selected as replacement for 4620, to TS8123 and TS8126 steels in the interests of better machinability and less distortion. Typical boron steel applications include 14B38 for axle shafts and draw bars, replacing 86xx; "43BV14" (0.03 to 0.09% V to reduce grain growth) for truck gears; and 80Bxx for 86xx in ring gears and pinions.

Mechanized Heat Treatment

Opinion is in close agreement that considerably more needs to be known about the carburizing process in general and carburized cases in particular. How thick should the case be for best performance of this particular gear? Is this depth also advisable for an axle shaft? How about carburizing bolts? What about the gradient type of case? Are there any further possibilities for homogeneous or "through" carburizing of low-carbon steels — a process which has found some application in spring stock? Is a 0.30 carbon steel with a 0.015-in. case a better bet than a 0.020 carbon with a 0.030-in. case? Why should it be necessary, for example, to straighten a third of all carburized ring gears in one plant using modern practices, when another producer regularly holds distortion to 0.001 in. per ft. of gear diameter?

You can get a lot of quick answers to the last question from metallurgists. They will tell you: "It's all a matter of design." They are probably right. This brings up the old but always controversial subject of cooperation between metallurgists and engineers who design parts. Teamwork needs to be better. Each group, for its own good, should know the abilities and limitations of the other.

QUENCHING PRACTICES

Confronted with a heat treated part which has failed in service, the metallurgist used to say simply: "Put in some more alloy." Now — for one reason because the alloy is not available — he looks more closely at heating and quenching practices, and also insists that the designer adopt a more realistic appraisal of the real needs of the part in service. He recognizes that, once you get 90 to 95% martensite in a quenched steel, all analyses perform pretty much alike. That throws the burden on quenching — that is to say, faster cooling down to the M_s point. Lowerators and other devices to speed the movement of heated pieces into the quench; agitation

or, more accurately, circulation of the quenching bath; specially compounded oils which have nearly as fast quenching action as water — these are a few of today's tools.

The high favor accorded heat treating equipment which can be integrated into the production line has been mentioned earlier. In furnaces, this means the continuous or through type, as against the so-called batch type. Selection of one or the other naturally will depend in large degree upon the size, shape and volume of the part being handled. Large quantities of identical parts may dictate the continuous furnace, in spite of its relatively high cost and the fact that furnace crews may spend most of their time sitting idly by. Of course, in the large automotive shops, continuous furnaces usually are the rule. They have been made so automatic by conveyers and controls that the only attendant needed is a workman who can remember which button to push.

However, there is a preference for the idea of "colony heat treatment" in many plants where a wide variety of parts are being processed. This involves a centralized department where groups of batch furnaces can be set up on cycles which fully utilize the time of furnace crews and equipment. Parts are routed from the various machining areas to "heat treat" and then go on for subsequent processing. This may mean more handling and some back-tracking, but it makes multi-purpose units of the batch furnaces. (They are also lower in first cost than continuous types.) The over-all result may be a more economical heat treatment.

Literature over the past 10 to 15 years is replete with details of austempering, martempering, marquenching and isothermal or cyclic annealing. The trend of recent months away from alloy steels to the carbon types may have dimmed slightly the importance of these relatively latter-day techniques. Thus, one automotive plant has discontinued isothermal annealing of forgings because the ones they now make have a lower alloy content, needing nothing more than a "delayed" normalizing at 1275° F.

On the other hand, commercial success attending hot oil quenching at 350 to 400° F. of carburized alloy steel gears has been so pronounced as to establish the martempering or marquenching process firmly. On automotive transmission gears of 4320, 4620 and 8620, for example, tooth tapers have been held well within allowable limits of 0.003 in. by hot oil quenching, without the need for any holding fixture or press, and at insignificant sacrifice of hardness.

It cannot be gainsaid that a more general and detailed knowledge of TTT-curves and TT-Hardness tempering diagrams has resulted in far more accurate "design" of such heat treatment procedures as short annealing cycles. In the same way, a better understanding of grain size control has simplified many carburizing problems, doing away with the old systems of repeated heating and cooling practiced in box carburizing.

A FEW MORE HIGHLIGHTS

A major contribution to the technology of microstructure, machinability and heat treatment of a wide range of steels was the second installment of the Air Force Machinability Report, released last summer, with the cooperation of a number of industrial companies, research laboratories and technical institutions. It throws welcome light on relationships between microstructures and machinability, with some interesting tabulations and correlated curves.

This brief high-spotting of top topics in the heat treating science (it's no longer an *art*) can by no means be all-inclusive, and is not so intended. There have been major improvements in furnace controls, temperature recorders, gas analyzers and the like. More extended use of electronic controls has meant faster response, greater accuracy and longer life of equipment due to the elimination of wearing parts.

One almost-human control system installed on some fluid-type carburizing furnaces comprises alloy wire sensing elements which change resistance with changing carbon content of the gas, and thus both record and control the furnace atmosphere.

Radiant tube furnaces have registered important advances. One unit combines tubes with a circulating fan to provide a "radivection" heating action. In addition, heat capacitors are built around the radiant tubes so that a "head" of heat can be built up for high initial input to a fresh charge.

Package-type atmosphere generators are available, highly portable and adaptable to various specialized needs.

Careful consideration of the economics of surface characteristics has directed atten-

tion to the decarburization which exists at the surface of most stock received from the mill and to various means for carbon restoration or skin recovery. Carbonitriding is one efficient method.

Improved neutral salt compositions are free from sulphites, sulphides and oxides.

Lithium compounds used as a means of removing oxygen and water vapor from furnace atmospheres suggest the possibility of simultaneous annealing and descaling.

Cold treatment — a form of heat treatment (?) which has attracted considerable attention in recent years — of screw driver bits at −120° F. for 1 hr., followed by immersion in boiling water and repeating this cycle five times, is said to improve service life up to fivefold. Liquid helium is used as the coolant. Contradictory opinions exist as to whether the treatment is worth the cost. It would seem that the principal if not the only advantage of refrigeration would be the transformation of austenites retained after a proper quench to room temperature, and physical changes of this sort take place slowly at subzero temperatures. Obviously, if the part has such a composition and mass and has been appropriately quenched to substantially pure martensite, subsequent refrigeration would have a dubious advantage.

Steam treatment of powdered iron compacts — also some cutting tools — forms a thin, hard surface layer of magnetic oxide which extends wear resistance either by virtue of its own structure or because it absorbs and holds lubricant tightly.

Selective flame hardening units of compact, efficient design are now adapted to production lines, one large automotive company having installed such a system to process camshafts for passenger car engines.

"Liquid flame hardening" is the term applied to a unique arrangement for hardening the teeth of 4140 gears by rotating several on a common shaft with the teeth and rims immersed in carburizing or neutral salts at 1525 to 1550° F. for about 4 min., quenching in oil at 150° F., and tempering at 430° F. for 45 min.

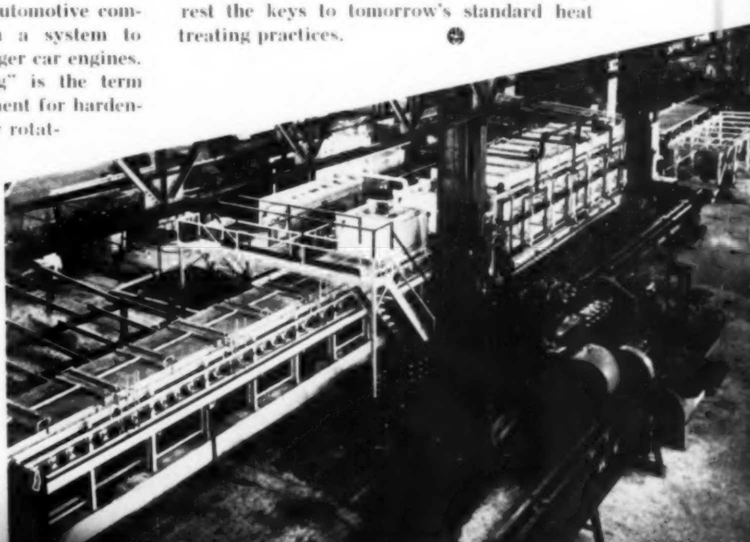
For the future, many metallurgists are convinced that their industry is just entering a whole new era in the heat treatment of alloys (in contradistinction to heat treatment of steels).

Thus: Some projections of the jet engine program hint at production figures of 18,000 units a month, which would call for an astronomical amount of high-temperature alloys. At the same time engine designers would like to push burner temperatures up far beyond 1500° F. in the interests of improved efficiency. All this will require stabilization heat treatments into the range of 2150° F. and even beyond in furnaces of revised designs and particularly with fixtures with low gross weight, able to stand up under intermittent heat.

Handling mechanisms for this type of work also will require extensive changes. In fact, even now the design of efficient heat treating equipment calls for a large measure of assistance from mechanical engineers and conveyer experts, along with electrical or metallurgical engineers.

Heat treatment of titanium alloys has progressed little beyond the infancy stage. Once research establishes what can be accomplished in the way of compounding alloys, as well as in realizing their maximum properties through heating and quenching, there may be still new demands on furnace designers.

There is no stopping change — in methods, equipment and operating details — for progress is change. In the metallurgical research and testing laboratories of today rest the keys to tomorrow's standard heat treating practices.



Surface Combustion Furnaces for Continuous Bright Annealing at Globe Steel Tubes Co., Milwaukee

By A. J. Langhammer, President, Amplex Division, Chrysler Corp., Detroit
Chairman, Subcommittee on Powder Metallurgy of American Ordnance Assoc. Shell Committee

Powder Metallurgy 1925–1950–19??

Every review of powder metallurgy the writer can remember tells how this branch of industry is based historically on the manufacture of coherent platinum rods from chemically refined powder. Some of them then go on to mention the metal-graphite mixtures for motor brushes, which (if not the very first) was among the first commercial applications of the idea that strong and useful combinations of metals and even metals and nonmetals, impossible to produce by conventional alloying, could be made by pressing the well-mixed powders and then heat treating the compacts. Such work in the electrical industry's laboratories led in 1916 to a porous metal bearing which could be impregnated with lubricating oil and sealed into portable equipment for a satisfactory lifetime of service without further attention.

During the 1920's another important step was taken in the discovery and development of methods for the manufacture of heavy-duty bearings. For the first time, bronze bearings made of metal powders were of such strength and quality that they could meet the requirements of automobile engines and even of much more massive machinery — this in contrast with the earlier ones which operated only under light loads. This transition to heavier work was, I believe, of prime importance; it was the one factor which has led the way in the expansion of the metal powder industry during the last 35 years.

A natural result was that larger and larger bearings (and other parts) were produced. We at Amplex have made a bearing that weighs 330 lb.; if required, we could make units two or three times as heavy. In line with this trend, producers of metal powders expanded their facilities, improved their products, and marketed new materials. A number of equipment manufacturers also contributed in presses, furnaces and other essential units of improved design, greater adaptability, more accuracy, and of heavier tonnage.

This advance in the manufacture of bearings ushered in a parallel development of finished machine parts. First they were of small size and simple shape; this was natural; it was equally natural that size, complexity, physical properties, accuracy and economies in the finished part should improve with the passing years. I firmly believe that this trend will continue; the possibilities are great, the fields of commercial application almost limitless.

Thus it is that at the present time powder metallurgy may be divided into four fields; namely, self-lubricating bearings, finished machine and ordnance parts, cutting tools and dies, and specialties. The last mentioned would include electronic requirements, magnets, filters and porous diaphragms, and the embryonic industry concerning itself with the rare and heavy metals, byproducts of uranium piles. We are primarily concerned with the first two, which were developed and gained popularity in that sequence.

Present Status — So much for the broad developments. The present year has seen a decided increase in the use of products made of iron powder, in large measure represented by finished machine parts. Moreover, the size of such parts in production quantities has increased. Not too long ago a unit of 2 in. in diameter was considered a large size; today we make parts in production quantities of finished machine parts that range in size from 4 to 8 in. in diameter. Occasionally we also make units of greater size. Not all manufacturers and engineers know that powder metal units of such large size are available from some producers.

During 1941 the use of nonferrous metal powders by Amplex Division, in comparison with ferrous metal powders, was in the ratio of 90% of the former and 10% of the latter. Today this gap is closed so that the proportion is of the order of 60 to 40%. In view of the vastly larger amount of iron that is available, this trend can be viewed as a siz-

able contribution to the conservation of the scarcer metals.

Bearings — Techniques and manufacturing equipment have been improved so that plain or barrel-type self-lubricating bronze bearings are now available at no cost penalty. With the flanged units, however, the economies are far more attractive through the metal powder product. Bearings of large size, 4, 6, 8 and even 10 in., likewise provide a saving in over-all costs. A further characteristic is that they positively solve operating and service problems. Compared with cast solid "bronzes", they have greater accuracy — which means much closer tolerances, cleaner, quieter operation, and longer life.

These achievements required lubricating oils of special qualities. One phase was to get a nongumming oil. Another need was an oil with low cold-test or pour-point. This was mandatory when our "Oilite" bearings were used on the delicate mechanisms of airplanes, stratosphere type, encountering temperatures of −40 to −60° F. What a tough job it would be to oil a bearing in North Pole weather with an oil can!

Oil-cushioned, self-lubricating bearings must generate an oil film which is continuous and unbroken under all conditions of load, temperature and friction. Obviously this has required continuous development of lubrication along with the metallurgical and mechanical phases of manufacture.

FINISHED MACHINE PARTS

In most instances a finished machine part from metal powders is just what the words say — it is a part ready for assembly on the production line. If any machining operations are necessary these are of minor caliber and include such items as an undercut, drilling, or drilling and tapping a hole, generally at right angles to the bore. More than 20 machine tool operations have been eliminated on some items. This, of course, provides for substantial savings in capital investment, and — what is often of prime importance — gets into production at a very fast pace. Even on units of irregular shape, parts difficult to produce, tooling time for presses, dies, and auxiliaries generally ranges

Briquetting Press in Production on Large Parts. Shown is Oilite oil-cushion heavy-duty self-lubricating bearing 11.83 in. outside diameter

from four to six weeks. In grim periods such as we are now experiencing this compares with a normal tooling period of 12 to 18 months for more conventional forge and machine shop programs. Then, too, the cost of tooling for powder metallurgy is very much less. Thus, we have had a tool cost of $12,000 against $500,000 for a certain automotive transmission part!

Costwise there is obviously a big advantage in favor of powder metallurgy parts, particularly where multiple machining operations are normally involved. Even without this advantage, Amplex Division has produced parts at a cost lower than that of a rough gray iron casting, unmachined, except for snagging. Here, too, there are additional hidden values and advantages; one is that assembly operations are forthright, whereas some hand fitting is frequently required on the rough casting. Another feature is that the powder metal product is a semi-precision unit, and it may be oil impregnated, or self-lubricated, a worth-while feature which is being recognized more and more by general industry. These latter two characteristics make for a smoother operating machine, less noisy, and one with components which make for longer life.

Another actual example of possibilities of favorable economics is displayed in a slide assembly. The cost of the two units was 43¢ in "Oilite", against a former cost of more than $2.00.

The advantages of finished machine parts are broad indeed. Included is greater freedom of design. No longer is it necessary to restrict engineering designs to parts that can be machined economically. As a matter of fact, we make quite a few finished machine parts which cannot be machined in the quantities required from existing machine tools.

During World War II large numbers of driving bands for 20-mm. projectiles were made of copper powder. Now more and more defense units are being made from metal powders. Included are driving bands of iron powder in calibers of 90 mm. and larger. This volume will be increased greatly as projects get rolling. Important aspects of this trend include a short period of time to get into quantity production, no normal tooling-up program, no production-line machine tools, jigs and fixtures, the release of much skilled man power for other defense work, and self-lubrication.

Some examples will be informative:

In production, one of our powder metal parts established a large saving in steel — that is, pounds required per part. Another item, a defense part, was formerly made from brass rods of special contour for which there is insufficient rolling and extrusion capacity; replaced with powder brass products they also provide a saving in raw material. Another instance is that of iron powder parts which replace another of nonferrous metal formerly used but which will not meet the present requirements.

There are a number of instances which could be quoted where powder metallurgy gives much broader scope to the ordnance engineer, due to its adaptability to numerous variables. Many parts are in production; still more are being studied and considered. Included are rolling mill products, forgings and parts that require extensive tooling-up and machining. Powder metallurgy not only provides an excellent alternate for strategic materials, but it also breaks production bottlenecks of various kinds.

RAW MATERIALS AND EQUIPMENT

The established American producers of metal powders and a few newcomers have recognized the future potentialities in this field. Facilities for making both nonferrous and ferrous powders have been increased in 1951 through plant expansions. Some major projects in the way of new factories are still in the stage of construction. Especially important are the ferrous or iron-base materials, which are, in many instances, splendid alternates for bronze, brass, and aluminum.

Conservation exists through the factor of porosity, controlled to meet the requirements of the part. Depending on manufacturing processes, porosity may be varied from practically zero (a solid condition) to 50% or even more. Actually, oil-cushion, self-lubricating bearings are a new material — perhaps better said, a new lightweight material. Normally, they weigh 25% less than a solid bearing or casting of the same dimensions. Even if they were no better otherwise, this represents conservation of metal in use.

Improvements have been effected in briquetting presses and other equipment. In our own plant we have presses that range

in tonnage capacity from 15 to more than 2000 tons. We do not feel that the size of a part (or of the necessary tools) is necessarily a deterrent, provided the economics are favorable for the process.

PHYSICAL PROPERTIES

For many years we have been asking for metal powders of better quality; powders that are reasonably uniform; powders having the necessary particle characteristics and purity to make for high physical properties in the finished part. While progress has been made recently in the latter regard, finished units of high physical properties are more generally obtained by means of advanced techniques by the parts maker.

Contributing to this advance is industrial research. Beginning in the late 1920's, this subsidiary of Chrysler Corp. has engaged in a program of continuous research and development. (Similar statements of course may be made concerning other firms in this field, although I will confine my remarks to apply to our own organization with which I am intimately familiar.) As time went on, working space, laboratory equipment, apparatus, and personnel were expanded. Frequently we call upon some of the 3000 members of the corporation's main engineering division and laboratories for supplementation and assistance.

Since iron and its alloys represent materials susceptible to much higher mechanical properties than those of copper and its alloys, the results of our research (other than a continuously expanding total volume of production) may be summarized by saying that the relative amount of iron-base product is now 40% of the total, and is steadily increasing.

FORWARD PICTURE

Much future work must be done in determining, understanding and eliminating variables in metal powders. We see no reason why a briquetting press, for example, should not be set up and put into operation as quickly as a lathe, milling machine or similar tool. In addition to uniformity, there is also a wide-open opportunity for powders that will yield higher physicals.

We have just stated that products of iron powder have not yet equaled in volume the production of units of nonferrous base. The foreseeable future, while calling for an increase in bearings and parts of nonferrous metal powders, is much more strongly in favor of products based on iron powder. Probably in 1952 iron powder will not only equal but surpass nonferrous material in volume. By 1955 iron powder products should be several times that of nonferrous.

All of this is predicated upon what might be termed normal expansion or development, and applies largely to civilian applications. It is presumed that just a few major applications for the defense program, if adopted, would alone require a tremendous tonnage of iron powder.

Steady improvement in the quality of product may be expected. The opportunities for new (or at least improved) combinations are practically unlimited, since the fabrication of parts by powder metallurgy can include such a broad variation in the choice of composition. It may be ferrous, nonferrous, simple metals, alloys, or inert materials (such as graphite, carbon or silica) in combination with one or more metals. Selected heat treatments then can make important changes in structure. Articles of controlled porosity may be impregnated or infiltered with liquids, plastics, or other more fusible metals. It is hard for an enthusiast to set limits!

Finally, I think it is certainly worthy of passing mention that the powder metal process has been a lifesaver in the study of many of the "new" metals (such as zirconium, titanium and uranium) and their conversion into usable forms rather than laboratory specimens. For the most part these metals are so reactive that conventional smelting, refining and fabrication methods are out of the question, and (at the present time at least) they are produced via powder metal. Fortunately for many of these new and important developments, sufficient information about powder metal operations was widely distributed and little or no delay has been encountered in the fabrication of sizable parts. In the future there will undoubtedly also be an important interchange of information, wherein the men who are working with the rare metals will develop techniques and processes which cannot help but be of advantage to the established firms already in the powder metallurgy business.

By Vernon A. Lamb, Chemist, Electrodeposition Section, National Bureau of Standards

Metal Cleaning and Finishing Since the War

During the war years the emphasis in research in the metal finishing field, as well as in other branches of technology, was on applied and developmental problems. As a result, very little of a fundamental and theoretical nature was published. In the years since the end of the war, activity in fundamental research has increased, leading to a respectable number of important contributions. At the same time, activity in developmental work has continued. Progress in both of these fields will be briefly described.

Availability of a variety of radioactive tracer elements, a product of wartime atomic energy research, has opened vast fields of exploration in every branch of science, and radioactive tracers have been applied to problems of current and metal distribution, mechanism of chromium plating, and cleanliness of surfaces.

Porosity of electrodeposits, which is of fundamental importance with respect to their corrosion protective value, has been studied by N. Thon and co-workers under the American Electroplaters' Society Research Project No. 6 at Princeton University. A new gas permeability test of porosity has been developed, application of which has yielded new and interesting information. Continuing studies of this subject, as well as studies in the related A.E.S. Project No. 13, on "Correlation of Weathering Behavior of Electrodeposited Coatings With Their Permeability to Gases" may make possible, for example, satisfactory corrosion protection with thinner deposits, thus aiding in conservation of critical metals.

Brenner and Senderoff of the National Bureau of Standards have devised an instrument for measuring stress in electrodeposits. Corrosion of a basis metal through stress-cracks in a plated coating has been often observed. Elimination of this type of failure would be an important contribution.

An interesting phenomenon termed micro-throwing power, or the ability of a deposit to plate into minute recesses, was the subject of a paper by C. E. Reinhard of the New Jersey Zinc Co. Low current density and high metal content of the bath favor this property, and acid baths have better micro-throwing power than cyanide baths. These results are important in connection with plating on powder compacts.

Attempts to plate a variety of metals at high temperatures and pressures were unsuccessful. Major interest was in the refractory metals such as molybdenum, tungsten, and titanium, which cannot be plated from aqueous solutions at ordinary conditions.

Cleaning and Surface Smoothing — Numerous publications and patents in the cleaning field have appeared which represent the progress that comes from many small improvements in well-known processes, equipment and materials rather than from any one new or outstanding development.

Multiple-phase cleaners, consisting of a mixture of an unemulsified solvent and a solvent emulsion, have been described. It is claimed that this type of cleaner is more effective than ordinary emulsion cleaners, especially in spray machines.

H. B. Linford and E. B. Saubestre at Columbia University, working on A.E.S. Research Project No. 12, "Cleaning and Preparation of Metals for Electroplating"[4], have made a valuable contribution in the form of a critical summary of the literature, and have developed a very sensitive degreasing evaluation test. The test is carried out by spraying the dried specimen with water from an atomizer.

In the field of pickling and descaling, the sodium hydride process introduced in 1945 is becoming more widely used. High costs of buffing and polishing and the shortage of skilled labor in this branch of metal finishing have stimulated use of the following chemical and electrochemical methods for achieving bright finishes.

1. Bright decorative and corrosion protective finishes have been achieved most extensively by the use of bright nickel deposits, which have come into almost universal use. It has been shown that deposits

from some bright nickel solutions have marked leveling power, that is, the surface of the deposit is smoother than that of the basis metal. Further research along this line may produce solutions that have this property in still greater degree, thus permitting coarser basis metal finishes.

2. An important process reported in 1947 by G. W. Jernstedt of the Westinghouse Electric Corp. is the "PR" (periodic reverse current) process, which results in marked leveling and brightening. This has been most successfully applied to the high speed cyanide copper type of bath.

3. Work in the early 1930's by the French scientist, P. Jaquet, stimulated much interest in electropolishing. C. L. Faust of Battelle Memorial Institute, as well as the steel companies, have done a large amount of development work in this field. The texture of an electropolishing surface is not the same as that produced by mechanical polishing and buffing, but consumer acceptance is sufficiently good that electropolishing is now widely used, particularly for stainless steel articles, at a substantial reduction in cost over mechanical polishing.

4. Chemical dip polishing solutions have been developed during the last three years by several firms, and has been most successfully applied to aluminum alloys.

The above methods have by no means displaced mechanical polishing, and there have been a number of developments in the latter field that reduce the costs and the amount of skilled labor required. Among these developments may be cited the following: *(a)* Use of more diversified automatic machines; *(b)* more extensive use of "prepolishing" of sheet stock before forming; *(c)* the use of back-stand equipment with factory-coated abrasive belts in place of headed wheels, in combination with improved contact wheels which are more adaptable to curved surfaces. Other advances include the development of liquid-base buffing compounds that are applied to the wheel by spraying to give more uniform application and less wastage of compound, and the improvements in barrel polishing.

Closely related to developments in smoothing are methods for measuring surface roughness. The various instruments for this purpose were described by H. J. Kellner at the symposium on smoothing held during the 1950 American Electroplaters' Society convention.

The hardness of chromium led to its use in gun bores to increase their resistance to abrasion and erosion. The most efficient thickness of deposit is still being studied, as well as methods of preparation and plating for specific applications. Chromium plate for improved wear resistance on items such as tools, dies, molds and piston rings is used increasingly.

Work on the common plating baths has for the most part been directed toward development of brightening addition agents. An improved chromium plating solution called the "self-regulating, high speed" solution was described by J. E. Stareck, F. Passal, and H. Mahlstedt of United Chromium, Inc.

Results of a comprehensive research conducted by the Bureau in cooperation with the American Electroplaters' Society reveal some interesting information on the physical properties of electrodeposited nickel. By varying the bath composition and its pH, temperature and current density, nickel deposits can be produced with tensile strengths from 40,000 to 200,000 psi. and Vickers hardness from 150 to 750. These and other studies reveal that the properties of nickel and chromium deposits are influenced by the content of oxygen, hydrogen or other elements. Considerable work is needed to determine the source, form and location of these inclusions in electrodeposits.

Baths from which nickel and cobalt can be deposited on steel and other metal surfaces by chemical reduction, that is, without current, were developed by A. Brenner and Grace Riddell of the National Bureau of Standards. An advantage is that nickel or cobalt can be readily deposited in recesses or in the bore of small tubes where anodes are impractical.

The production of electro-tinplate has grown until, in 1950, 65% of all this material was made by this method.

During the last few years, fluoborates of copper, tin, lead, zinc, and other metals have become available and their use in plating solutions has been promoted. In general, higher current densities can be applied than with the commonly used acid baths based on sulphates, and use of fluoborate baths will probably increase.

Investigation of alloy plating systems

has been actively conducted during the past several years. Tin-zinc and lead-tin alloys are good substitutes for cadmium and zinc respectively on steel.

Among other electroplated alloys for which baths have been developed are copper-cadmium, cobalt-tungsten, nickel-tungsten, iron-tungsten, copper-germanium, tin-cadmium, chromium-indium, chromium-molybdenum, nickel-rhenium, and cobalt-phosphorus. Most of these do not have applications at present, but use for them may develop. The cobalt-tungsten and cobalt-phosphorus alloys have high initial hardness (500 to 700 Vickers) and the ability to harden further on heat treatment.

Several excellent reviews of the methods available for plating on aluminum have appeared, and improvements in methods for producing adherent zinc immersion deposits as a base for plating have been described. In the field of anodic aluminum coatings there has been little change during the last few years. The use of dyed anodic coatings on a wide variety of household items and novelties is now common.

Several papers concerned with procedures for plating on magnesium have been written. H. K. DeLong of the Dow Chemical Co. has developed a process based on a zinc immersion deposit. Magnesium alloy parts prepared by this process and plated with 0.0005 in. of nickel were uncorroded in indoor service after two years.

A new type of finish for magnesium described as an "electrolytically produced refractory ceramic coating" has been developed by H. A. Evangelides of Frankford Arsenal. The coating has excellent corrosion, abrasion, and heat resistance and is a good paint base. Treated parts painted with a zinc chromate primer and a baking enamel have withstood thousands of hours of salt-spray exposure. The process is available for defense applications.

The largest and most logical field of application for electroforming is for production of articles which cannot be made cheaply by conventional fabricating methods and which are of thin enough section that excessive deposition periods are not required. Increasing use is being made of this method of manufacture. Among the newer applications, some of which are mass-production items, are band instruments, screen, tubing, pen caps, wave-guides, venturi tubes, computing pin cams and plastic molds. Copper, nickel, and iron are the most commonly used metals for electroforming. It is safe to predict that the use of electroforming as a fabricating method will continue to grow.

There has been increased recognition of the importance of specifications. Specifications covering thickness, adhesion, appearance, and porosity of coatings, prepared jointly by the American Society for Testing Materials and the American Electroplaters' Society, are now available for the commonly applied metals. Preparation of Government specifications is in progress. Wider use of these specifications will benefit both the consumer and the plating industry.

EQUIPMENT AND INSTRUMENTS

Increased use of cathode compartment diaphragms, introduction of oil-immersed rectifiers, and development and availability of a wide variety of synthetic resin materials for tank linings and for protecting other equipment such as pipe, pumps, and racks from almost any solution or chemical used in the plating industry, are among the highlights in equipment development. Automatic instrumentation for temperature, pH, level, and current control is becoming more common. Tantalum heating coils, corrosion-proof to all acids except hydrofluoric, are an important innovation. The list of new things in this field could be long, but space does not permit completeness.

Advances in any field are often related to the progress in measuring instruments. For example, the present trend toward thickness specifications for plated coatings is speeded by the availability of simple thickness measuring instruments for rapid and reliable nondestructive testing of a large number of samples.

Following are some of the instruments and tests that have been recently described:

1. Methods of measuring thickness have been reviewed and comparative studies of the accuracy of different methods have been made by H. J. Read and co-workers at Pennsylvania State College under the A.E.S. Research Program. A modified magne-gage for composite copper-nickel coatings was described by A. Brenner and E. Kellogg of the National Bureau of Standards. A new time-of-gassing test for cadmium coatings

was devised by S. G. Clarke and J. F. Andrew of the British Armament Research Department.

2. Quantitative measurement of adhesion of electrodeposits has been studied actively. A. L. Ferguson and co-workers at the University of Michigan, under the American Electroplaters' Society research program, reviewed the literature and discussed all known methods. They proposed attaching a "handle" to the plate by a synthetic resin adhesive. This obviously is limited to relatively weak adhesion.

The "nodule" method described by A. Brenner and Virginia D. Morgan of the National Bureau of Standards is applicable to deposits up to a few thousandths of an inch thickness and does not require machined specimens. In the nodule method, a small mushroom-shaped nodule is plated on the coating. The adherence of the coating is then measured by the force that is needed to detach a small area of the coating under the nodule. This method is not yet in extensive use.

3. A simple instrument for surface tension measurement consisting of two glass plates held together at a very small angle was described by Joseph B. Kushner. It should find application for control of wetting agents.

4. Another property of coatings that may affect their usefulness is the stress that may develop in a coating during its deposition. If this stress is high, the coating is likely to crack in service. An instrument known as a spiral contractometer was devised to measure the stress during deposition. When metal is deposited on a spiral strip, any contractile stress causes movement of a needle that is geared to the lower free end of the spiral. From the extent of this movement, the stress can be readily computed. Measurements with this instrument might well serve to show the presence of impurities that increase the stress, and thus permit better control of the baths.

5. Hot hardness of nickel and chromium coatings is of importance in certain military applications. The micro-hot-hardness tester,

Exit End of 54-In. Continuous Electrolytic Cleaning Line in Sheet and Tin Mill, Columbia Steel Co., Pittsburg, Calif. Cleaning tanks at left center, coiler in right foreground

an instrument applicable to thin coatings, was described by A. Brenner.

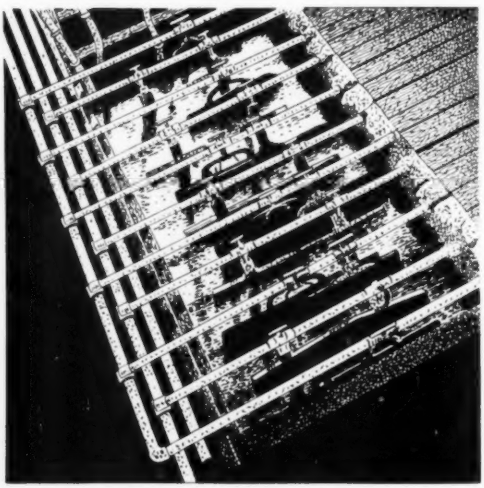
Substitute finishes to compensate for the shortage of plating metals are receiving serious attention. The commonly used copper-nickel-chromium system on steel and on zinc-base die castings is being modified by employing thicker copper and thinner nickel layers. Bright zinc finished with a clear chromate supplementary coating plus a clear lacquer, or white brass plus chromium plus a clear lacquer, are other substitute systems which in some applications have proved superior to copper-nickel-chromium. A more extensive use of the phosphate, chromate and black oxide coatings and supplementary organic finishes is probable in this program.

Conservation of materials by means of waste recovery systems is important and often economically advantageous, even in normal times. Recovery systems based on rinse salvage by evaporation and by ion exchange methods have been described.

FUTURE DEVELOPMENTS

It is extremely difficult to attempt to foretell the trend of future developments in electroplating.

There is a demand for pure coatings of molybdenum, tungsten, titanium, zirconium, beryllium and aluminum for important industrial and military uses. An intensive research program on this subject is in progress at the National Bureau of Standards. Because it is very improbable that deposition of these metals can be accomplished from aqueous solutions, studies are now being made on nonaqueous baths. These are of two types: Those in which suitable metallic salts are dissolved in organic solvents to yield conducting solutions; and fused salt baths, usually operated at relatively high temperatures.



As an example of the possibilities in this extensive and difficult research field, a report has just been published describing a new type of organic bath for depositing aluminum. The bath consists of aluminum chloride dissolved in ordinary ether and contains also lithium or aluminum hydride. The presence of the hydride leads to production of dense, ductile deposits of aluminum, which will probably find use in plating other metals with aluminum and in electroforming wave guides for radio communication. It remains to be seen whether analogous baths may prove suitable for depositing other metals.

Probably the most important development in the metal finishing industry as a factor in future progress is the wide interest in the necessity and value of research, both fundamental and applied. This attitude is best exemplified by the large program sponsored by the American Electroplaters' Society during the last six years. At the present time eight projects are active. Five additional projects have either been completed or the work has been suspended. Most of these have already been noted in this review.

The remaining projects will be listed to indicate the scope of the program: Stripping of copper from various base metals; determination of impurities in plating solutions; effect of surface finishing of nonferrous base metals on the protective value of plated coatings; effects of impurities and purification of electroplating solutions; polarization of electrodes in electroplating processes; disposal of plating room wastes.

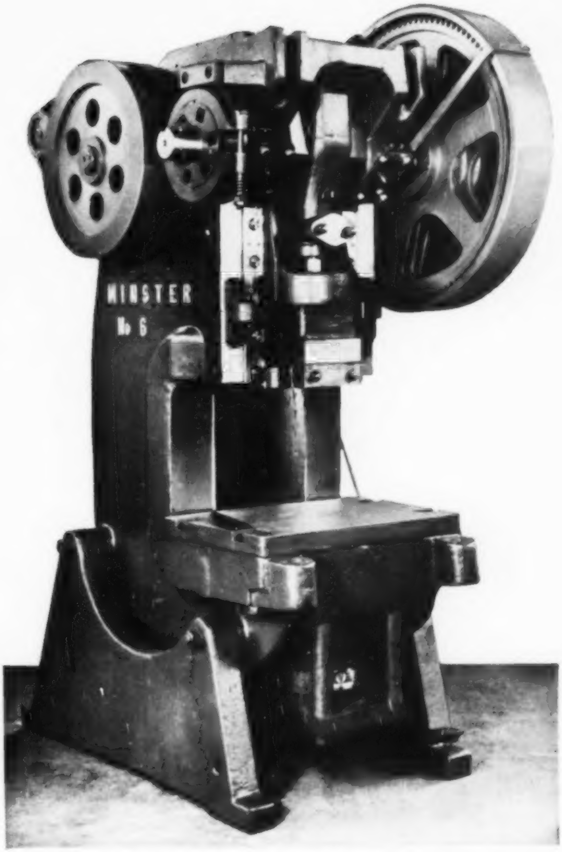
In addition to the above program, electrodeposition research is being done by Government laboratories, metal suppliers, plating supply firms, large users of plating, research institutions, and universities, and much of this is being reported. All of this effort is certain to result in progress.

Efficiency of

MINSTER PRESSES

Improved by use of

NICKEL ALLOYED IRONS, STEELS and BRONZES



Nickel alloyed castings and forgings are used for vital components in the Minster line of mechanical power presses . . . which range from 12 tons to 1500 tons capacity.

THIS OPEN BACK inclinable press cuts handling costs. Not only can it deliver 60-ton pressure at the bottom of the stroke, but it permits a wide range of feed direction, parts ejection and scrap handling.

Moreover . . . to improve its performance and service life . . . the builder, The Minster Machine Company of Minster, Ohio, utilizes high strength nickel cast iron frames, nickel bronze bearings and forged nickel steel clutch parts.

Main frame and all component castings are produced in Minster's own foundry, from high tensile nickel alloy iron containing 0.90 to 1.75% nickel, depending upon use.

Ellwood City Forge Company of Ellwood City, Pa., forged all clutch throwout and striking parts from heat treated Type 2350 (3½% nickel) steel. This high carbon nickel steel provides stamina to withstand the high stress which occurs when the crankshaft accelerates from "idle" to "full speed" within a fraction of a second.

All bushing for crankshaft bearings, and for lower connection bearings are of 1½% nickel bronze . . . cast by Ryder Brass Foundry of Bucyrus, Ohio.

At the present time, the bulk of the nickel produced is being diverted to defense. Through application to the appropriate authorities, nickel is obtainable for the production of engineering alloys for many end uses in defense and defense supporting industries.

EMBLEM OF INCO SERVICE

TRADE MARK

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Temperature Conversions

−459.4 to 0

C		F
−273	−459.4	
−268	−450	
−262	−440	
−257	−430	
−251	−420	
−246	−410	
−240	−400	
−234	−390	
−229	−380	
−223	−370	
−218	−360	
−212	−350	
−207	−340	
−201	−330	
−196	−320	
−190	−310	
−184	−300	
−179	−290	
−173	−280	
−169	−273	−459.4
−168	−270	−454
−162	−260	−436
−157	−250	−418
−151	−240	−400
−146	−230	−382
−140	−220	−364
−134	−210	−346
−129	−200	−328
−123	−190	−310
−118	−180	−292
−112	−170	−274
−107	−160	−256
−101	−150	−238
−96	−140	−220
−90	−130	−202
−84	−120	−184
−79	−110	−166
−73	−100	−148
−68	−90	−130
−62	−80	−112
−57	−70	−94
−51	−60	−76
−46	−50	−58
−40	−40	−40
−34	−30	−22
−29	−20	−4
−23	−10	14
−17.8	0	32

0 to 100

C		F	C		F
−17.8	0	32	10.0	50	122.0
−17.2	1	33.8	10.6	51	123.8
−16.7	2	35.6	11.1	52	125.6
−16.1	3	37.4	11.7	53	127.4
−15.6	4	39.2	12.2	54	129.2
−15.0	5	41.0	12.8	55	131.0
−14.4	6	42.8	13.3	56	132.8
−13.9	7	44.6	13.9	57	134.6
−13.3	8	46.4	14.4	58	136.4
−12.8	9	48.2	15.0	59	138.2
−12.2	10	50.0	15.6	60	140.0
−11.7	11	51.8	16.1	61	141.8
−11.1	12	53.6	16.7	62	143.6
−10.6	13	55.4	17.2	63	145.4
−10.0	14	57.2	17.8	64	147.2
−9.4	15	59.0	18.3	65	149.0
−8.9	16	60.8	18.9	66	150.8
−8.3	17	62.6	19.4	67	152.6
−7.8	18	64.4	20.0	68	154.4
−7.2	19	66.2	20.6	69	156.2
−6.7	20	68.0	21.1	70	158.0
−6.1	21	69.8	21.7	71	159.8
−5.6	22	71.6	22.2	72	161.6
−5.0	23	73.4	22.8	73	163.4
−4.4	24	75.2	23.3	74	165.2
−3.9	25	77.0	23.9	75	167.0
−3.3	26	78.8	24.4	76	168.8
−2.8	27	80.6	25.0	77	170.6
−2.2	28	82.4	25.6	78	172.4
−1.7	29	84.2	26.1	79	174.2
−1.1	30	86.0	26.7	80	176.0
−0.6	31	87.8	27.2	81	177.8
0.0	32	89.6	27.8	82	179.6
0.6	33	91.4	28.3	83	181.4
1.1	34	93.2	28.9	84	183.2
1.7	35	95.0	29.4	85	185.0
2.2	36	96.8	30.0	86	186.8
2.8	37	98.6	30.6	87	188.6
3.3	38	100.4	31.1	88	190.4
3.9	39	102.2	31.7	89	192.2
4.4	40	104.0	32.2	90	194.0
5.0	41	105.8	32.8	91	195.8
5.6	42	107.6	33.3	92	197.6
6.1	43	109.4	33.9	93	199.4
6.7	44	111.2	34.4	94	201.2
7.2	45	113.0	35.0	95	203.0
7.8	46	114.8	35.6	96	204.8
8.3	47	116.6	36.1	97	206.6
8.9	48	118.4	36.7	98	208.4
9.4	49	120.2	37.2	99	210.2
			37.8	100	212.0

100 to 1000

C		F	C		F
38	100	212	260	500	932
43	110	230	266	510	950
49	120	248	271	520	968
54	130	266	277	530	986
60	140	284	282	540	1004
66	150	302	288	550	1022
71	160	320	293	560	1040
77	170	338	299	570	1058
82	180	356	304	580	1076
88	190	374	310	590	1094
93	200	392	316	600	1112
99	210	410	321	610	1130
100	212	413.6	327	620	1148
104	220	428	332	630	1166
110	230	446	338	640	1184
116	240	464	343	650	1202
121	250	482	349	660	1220
127	260	500	354	670	1238
132	270	518	360	680	1256
138	280	536	366	690	1274
143	290	554	371	700	1292
149	300	572	377	710	1310
154	310	590	382	720	1328
160	320	608	388	730	1346
166	330	626	393	740	1364
171	340	644	399	750	1382
177	350	662	404	760	1400
182	360	680	410	770	1418
188	370	698	416	780	1436
193	380	716	421	790	1454
199	390	734	427	800	1472
204	400	752	432	810	1490
210	410	770	438	820	1508
216	420	788	443	830	1526
221	430	806	449	840	1544
227	440	824	454	850	1562
232	450	842	460	860	1580
238	460	860	466	870	1598
243	470	878	471	880	1616
249	480	896	477	890	1634
254	490	914	482	900	1652
			488	910	1670
			493	920	1688
			499	930	1706
			504	940	1724
			510	950	1742
			516	960	1760
			521	970	1778
			527	980	1796
			532	990	1814
			538	1000	1832

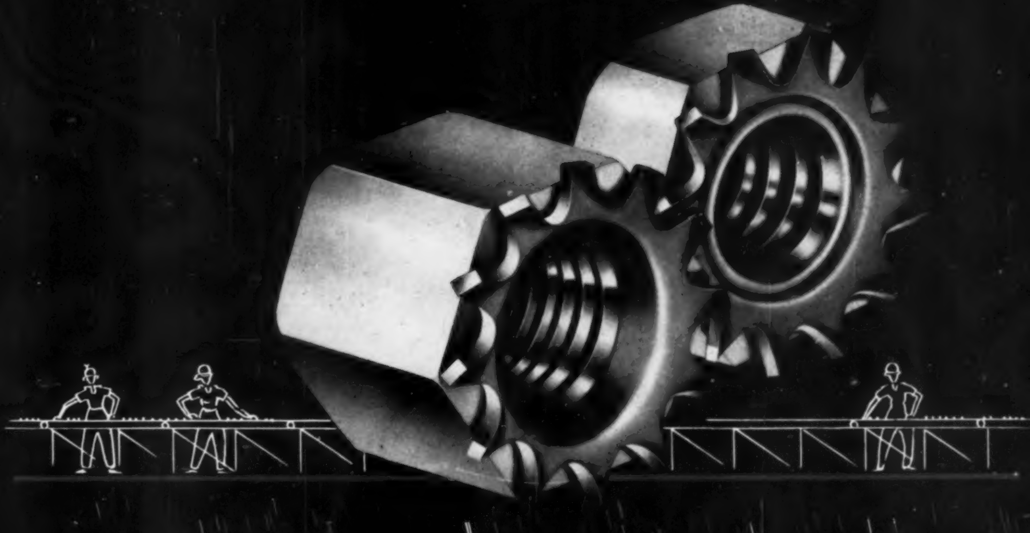
1000 to 2000

C		F	C		F
538	1000	1832	816	1500	2732
543	1010	1850	821	1510	2750
549	1020	1868	827	1520	2768
554	1030	1886	832	1530	2786
560	1040	1904	838	1540	2804
566	1050	1922	843	1550	2822
571	1060	1940	849	1560	2840
577	1070	1958	854	1570	2858
582	1080	1976	860	1580	2876
588	1090	1994	866	1590	2894
593	1100	2012	871	1600	2912
599	1110	2030	877	1610	2930
604	1120	2048	882	1620	2948
610	1130	2066	888	1630	2966
616	1140	2084	893	1640	2984
621	1150	2102	899	1650	3002
627	1160	2120	904	1660	3020
632	1170	2138	910	1670	3038
638	1180	2156	916	1680	3056
643	1190	2174	921	1690	3074
649	1200	2192	927	1700	3092
654	1210	2210	932	1710	3110
660	1220	2228	938	1720	3128
666	1230	2246	943	1730	3146
671	1240	2264	949	1740	3164
677	1250	2282	954	1750	3182
682	1260	2300	960	1760	3200
688	1270	2318	966	1770	3218
693	1280	2336	971	1780	3236
699	1290	2354	977	1790	3254
704	1300	2372	982	1800	3272
710	1310	2390	988	1810	3290
716	1320	2408	993	1820	3308
721	1330	2426	999	1830	3326
727	1340	2444	1004	1840	3344
732	1350	2462	1010	1850	3362
738	1360	2480	1016	1860	3380
743	1370	2498	1021	1870	3398
749	1380	2516	1027	1880	3416
754	1390	2534	1032	1890	3434
760	1400	2552	1038	1900	3452
766	1410	2570	1043	1910	3470
771	1420	2588	1049	1920	3488
777	1430	2606	1054	1930	3506
782	1440	2624	1060	1940	3524
788	1450	2642	1066	1950	3542
793	1460	2660	1071	1960	3560
799	1470	2678	1077	1970	3578
804	1480	2696	1082	1980	3596
810	1490	2714	1088	1990	3614
			1093	2000	3632

2000 to 3000

C		F	C		F
1093	2000	3632	1371	2500	4532
1099	2010	3650	1377	2510	4550
1104	2020	3668	1382	2520	4568
1110	2030	3686	1388	2530	4586
1116	2040	3704	1393	2540	4604
1121	2050	3722	1399	2550	4622
1127	2060	3740	1404	2560	4640
1132	2070	3758	1410	2570	4658
1138	2080	3776	1416	2580	4676
1143	2090	3794	1421	2590	4694
1149	2100	3812	1427	2600	4712
1154	2110	3830	1432	2610	4730
1160	2120	3848	1438	2620	4748
1166	2130	3866	1443	2630	4766
1171	2140	3884	1449	2640	4784
1177	2150	3902	1454	2650	4802
1182	2160	3920	1460	2660	4820
1188	2170	3938	1466	2670	4838
1193	2180	3956	1471	2680	4856
1199	2190	3974	1477	2690	4874
1204	2200	3992	1482	2700	4892
1210	2210	4010	1488	2710	4910
1216	2220	4028	1493	2720	4928
1221	2230	4046	1499	2730	4946
1227	2240	4064	1504	2740	4964
1232	2250	4082	1510	2750	4982
1238	2260	4100	1516	2760	5000
1243	2270	4118	1521	2770	5018
1249	2280	4136	1527	2780	5036
1254	2290	4154	1532	2790	5054
1260	2300	4172	1538	2800	5072
1266	2310	4190	1543	2810	5090
1271	2320	4208	1549	2820	5108
1277	2330	4226	1554	2830	5126
1282	2340	4244	1560	2840	5144
1288	2350	4262	1566	2850	5162
1293	2360	4280	1571	2860	5180
1299	2370	4298	1577	2870	5198
1304	2380	4316	1582	2880	5216
1310	2390	4334	1588	2890	5234
1316	2400	4352	1593	2900	5252
1321	2410	4370	1599	2910	5270
1327	2420	4388	1604	2920	5288
1332	2430	4406	1610	2930	5306
1338	2440	4424	1616	2940	5324
1343	2450	4442	1621	2950	5342
1349	2460	4460	1627	2960	5360
1354	2470	4478	1632	2970	5378
1360	2480	4496	1638	2980	5396
1366	2490	4514	1643	2990	5414
			1649	3000	5432

Where 1+1=1.....



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For information on Titanium Developments contact Mallory-Sharon Titanium Corp., Indianapolis 6

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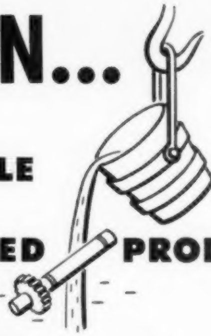

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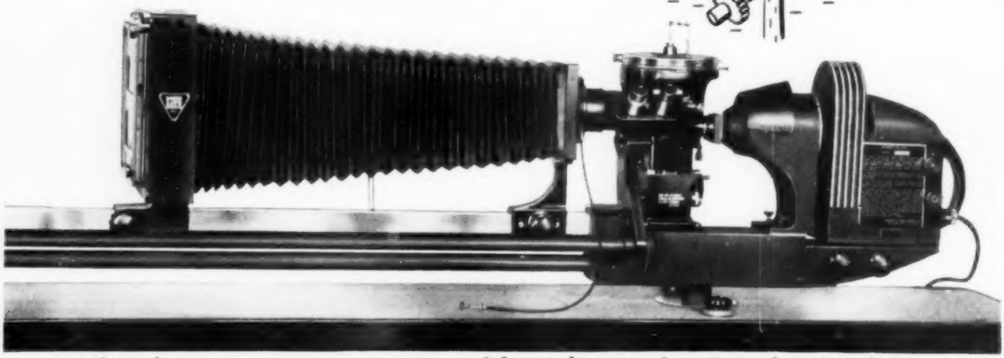

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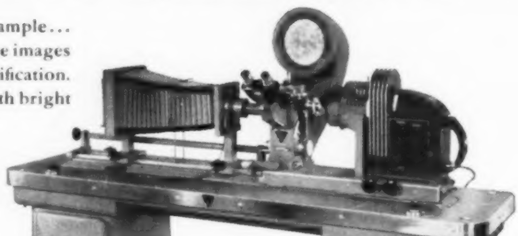

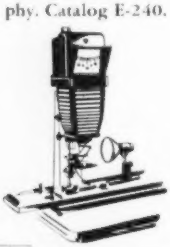

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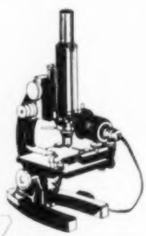

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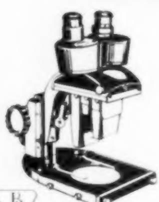

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By Keith F. Finlay, Research Engineer, Northrop Aircraft, Inc., Hawthorne, Calif.

Light Metal Castings for Aircraft Structures

It is fair to say that recent progress in aircraft and in jet engines has been due not nearly so much to the discovery of new and better materials of construction as to a better use of those excellent ones already at our disposal — that is to say, recent progress is due to refinements in old designs and to entirely new aircraft. Probably for that reason the designer and the metallurgist work more closely together in our industry than in many others using large quantities of superior metals and alloys. Consequently any review of nonferrous advances, if written by a metallurgist in the aircraft industry, cannot help but reflect the interplay between designer and constructor on the one hand and the metal producer and parts fabricator on the other. Likewise, such an author will think mostly in terms of the strong aluminum alloys.

With the above limitations in mind, let us take a peek into that enticing realm of "new revelations", fully cognizant that it would be fatal to discount many recent advances in the application of materials to structures. The very fact that such progress is being made along conventional lines gives a clue to the potentialities for further developments — even some of quite revolutionary character.

Few structures will survive close inspection without causing some questions as to the suitability of the materials employed. The natural tendency of designers is to lean heavily on precept and experience; they instinctively feel it is good insurance against getting "over their heads" in the use of untried materials. How be it, faster, bigger and better aircraft will require some revolutionary design concepts. Furthermore, there simply are not enough of the more critical metals for anticipated programs of production. Both these facts will require some radical departures from normal practices.

The more venturesome designer is sometimes a victim of his own imagination. His excesses, however costly to the individual designer, usually contribute to the over-all knowledge and, in time, pay dividends to himself and to his technical brethren. Whatever the degree of criticism brought down upon the bold designer, his reputation usually survives and is generally better than those of his more dogmatic contemporaries.

An inviolate requirement of a progressive designer is that he be endowed with second sight in his analyses of the potentialities — as well as the limitations — of a conventional material or fabrication process which he wishes to utilize in a new way. To be specific: One of the most popularized "new" materials to appear on the scene is titanium. Enthusiasts refer to it as the paragon, possessing all virtues as an engineering material. These same proponents have not yet told us how they intend to formulate an alloy strong enough to pay the freight (its density is twice that of the old reliable 24S and 75S aluminum alloys). They should also realize that the strong new alloys must be reasonably workable and capable of fabrication, else we will be no further along than we are now with the austenitic stainless steels, cold worked to a high degree of hardness and strength. Furthermore, some damaging characteristics already have appeared: Some titanium alloy sheet produced for test is susceptible to stress corrosion, and although its corrosion resistance by itself is phenomenal, in contact with some other materials it is extremely susceptible to galvanic corrosion.

Titanium, like other materials, will be limited in its applications to some degree, due to its fabrication characteristics. Metallic structure, as well as general physical characteristics, requires a very fine balance when choosing any new material for structural design in order that its advantages may be exploited.

LIGHT ALLOY CASTINGS

Of considerable interest to progressive designers are light alloy castings. They have gained considerable favor, especially in aircraft and hardware products. It is a rather unhappy commentary on modern

engineering acumen that the practices employed in the production of light alloy castings essentially reflect the technologies of the Ming Dynasty in China. This is not intended as a hollow criticism of the American foundry industry, but rather as a prelude to a discussion of the potentialities within the capacity of foundrymen to perform in the not too distant future.

Many of our new structures are so arranged that the service stresses are distributed so as to discount the stress in some components. A typical example is the structure in which the primary loads are supported by a shell type of component. The rigidity of the shell (and its ability to carry the loads for which it is designed) is often dependent upon the relative location of certain parts of the shell — their spacing is such that certain components fulfill no other useful purpose. In a case like this, it is conceivable that large, heavily loaded structures could incorporate extremely intricate light alloy castings to perform this stiffening function in a manner defying competition by any other means. Such auxiliary parts are likely to have a very intricate configuration — which, of course, is one of the most attractive advantages of castings. Great savings in fabrication time as well as economy of material will result from this use of castings.

Rocket Used by Army Air Forces Guided Missiles Division to Explore Upper Air. Courtesy U. S. Air Forces

In considering the use of light alloy castings for structural applications, the author calls attention to large concrete buildings or bridges. By itself, the best concrete is quite unsatisfactory for such structures, and, in the absence of reinforcing members, would never have been used to anywhere near the degree it is found in architecture today.

Let me draw a parallel between concrete and cast magnesium alloys. It is estimated that the weight-strength ratio of cast magnesium alloy could be significantly improved by inserting reinforcing elements in line with the stress patterns imposed on the castings in service. These reinforcing members may be applied primarily so as to increase the strength in bending — a type of stress which represents a goodly portion of those encountered.

Examination of foreign castings, especially German, made during World War II, as well as performance data collected during that war on the capacity of these products to survive severe service, is ample justification for wholesome respect of foundry technology abroad. It is apparent that the design practices, even though they were much more liberal than our own, produced the desired results. In comparing aircraft built in Germany during 1935–1945 with those made in the United States, it has been argued that we would never agree, in the interest of pilot safety, to the Germans' liberality and their low design factors. These factors, as practiced in American industry, represent a significant penalty. Our tendency to over-design beyond reasonable limits in the absence of pinpoint criteria, and then relax these requirements as experience is gained in their *own* operations, seems a slow and burdensome approach to an increased efficiency of our own metal products.

HEAT TREATMENT VERSUS DIMENSIONAL ACCURACY

It surprised many American metallurgists and designers to learn that many magnesium castings on enemy aircraft were used in the as-cast condition. This enabled the Germans to avoid one of our prime difficulties. We demand heat treatment, even though it results in warpage, cracking and residual stresses and even though the func-

tion of the casting may often be fulfilled in the absence of heat treatment.

In this connection it is interesting to note the increasing attention given by progressive metallurgists in the United States to foundry processes which aim at controlling the speed of cooling in the solidification range. At least one notable exponent of this process of thermal control and predictable grain nucleation gradients has demonstrated its soundness on a commercial scale. One very beneficial result has been an extremely high dimensional fidelity.

Another marked dissimilarity between the use of light alloy castings in the United States and in Europe is the relative satisfaction derived from as-cast surfaces and dimensions. Whereas most light alloy castings found in American products have been machined to a large degree, the European practice of utilizing as-cast surfaces takes advantage of the economies which can be derived. Of the two general classifications of casting dimensions and contours, the machine joint and the section rigidity contour, the second probably represents the preponderance in machine design. It has been said that a satisfactory as-cast surface is less susceptible to mechanical failure under given loads than a surface which has been "mutilated" by machining. Removal of material is usually justified in the minds of aircraft engineers because of the "ounces" saved. This often is a demonstrable fallacy in terms of the requirements for the part as a structural or nonstructural component.

For attaining high dimensional fidelity in castings and thus minimizing subsequent machining, the "semiforging" process is of interest. This involves the sizing or coining of oversize castings in precision dies — usually castings themselves. By this method, as-cast parts are held to dimensions within normal tolerances of finished parts. An additional advantage is that the original cast structure is wrought to a certain extent. It has been demonstrated that this change of microstructure is accompanied by a noteworthy increase in ductility. Further tests of this process are underway. It is believed that this operation will be fairly widely used in the aircraft industry in the not too distant future.

Reductions of an oversize casting in the order of 30% have been sufficient to produce an extremely ductile part. The limitations as to configurations are, in general, those characterized by the forging process. Many brackets and other parts, normally cast, may be treated in this manner. Ford Motor Co. of Canada, I believe, has coined its cast crankshafts during the annealing heat — primarily to increase dimensional accuracy and balance, and to decrease machining expense. Reductions in this case are very minor — a fraction of 1%.

INTEGRATION OF MULTIPLE DETAILS

Integration of multiple aircraft details into one large casting of a light alloy has been resisted, to a large extent, by the unimaginative approach of designers and foundrymen alike. The origin of this resistance stems largely from a sort of folklore belief that cast metal will not withstand dynamic loading — a belief that is entirely unjustified in view of the remarkable damping capacity of most light alloy castings. Resistance to change among foundrymen has also arisen from the satisfactory relations which have existed with their automotive and railroad customers. A rather violent transformation will occur whenever automotive equipment starts to apply lightweight construction with lighter materials, as will eventually be necessary because of the increasing cost of fuels and tires and their decreasing supply.

The broad application of steel castings in the automobile, industrial equipment and railroad industries has aided the airframe engineer in justifying an increased number of steel castings in his products. Whereas the current trend toward higher density structures in aircraft is predominant, it is also true that weight-strength ratio of heat treated steel is often extremely attractive. Foundrymen are therefore growing more aware of the quality requirements for aircraft, and this is accelerating the use of steel castings. Again, "sales resistance" is being broken down by certain inevitable conditions; as for these, critical supply, economic and product requirements lead the way.

In closing, the author wishes to modify the severity of this criticism of the *status quo* and qualify his approach to the topic by reiterating the question foremost in his mind most of the time: "*Quo vadis*, castings engineer?"

By Taylor White, Mechanical and Metallurgical Engineer

Advances in Machining and Cutting Operations

"SCIENTIFIC MANAGEMENT" — that system of avoiding waste labor through improved machines, tools, mechanical handling, and economy of human motions — was invented by a man working in the machine shops of Bethlehem Steel Co. in the late 1890's. Frederick W. Taylor was this great American engineer. He had already made a name for himself in a study of existing toolsteels for Sellers' (the machine-tool firm) and Cramp's (the shipbuilders). It was only natural that Taylor would continue with his experimentation — this time in association with Maunsel White — that resulted in 1900 in a tool that cut at several times the speed of the best of the previous ones.

A detailed history of the development of toolsteels is one requiring a book in itself. It is the story of a near-century of progress, commencing with the discovery that a little chromium ore charged into the crucible made a harder steel. Another important milestone was Robert F. Mushet's discovery (about 1870) that if the toolsteel contained considerable percentages of both tungsten and manganese it was hard after it had cooled slowly in air. Taylor's choice for Sellers and Cramp was between the air-hardening W-Mn (Mushet) English steel and Midvale Steel Co.'s W-Cr composition.

It is worthy of remark that the only aim prior to 1900 was to improve the toolsteels so they could cut harder and harder metal. At Bethlehem, Taylor and White approached the matter from a fundamentally different direction. They wanted a tool that would cut faster and last longer — "scientific management", you see! Shop performance of both the Mushet and the Midvale steels was quite variable, and in running down the cause of the trouble in the favored Midvale analysis (W-Cr-C) the heat treatment which induced red hardness was discovered, and we were suddenly in the age of high speed mass production (even though it took most American manufacturers 10 to 20 years to appreciate that fact).

As far as high speed toolsteel is concerned, subsequent improvements have come by perfecting the analysis — or rather devising analyses best for several broad classes of machine work. Simultaneously, metallurgists were studying the materials of construction — wrought iron, mild, medium and hard carbon steels, alloy steels (nickel, chromium, vanadium, molybdenum, silicon, manganese) wrought and cast, and especially the finishing operations whereby each grade or analysis could be improved by some form of heat treatment to obtain special properties.

There was no revolutionary discovery in the art of cutting these improved metals, however, until the advent of cemented tungsten carbide, and its later embodiments with tantalum carbide, boron carbide and others. They are the result of much study in the combined uses of heat treatment cycles and atmospheres, metal and carbon powders, pressure of compacting, and binders. Such powder metallurgical materials are so different from the conventional metals and alloys that one can hardly conceive of any similarity between them and the predecessor groups. The diamond, or the hard oxide used in grinding, is not mentioned, as it really is an auxiliary stage in tool development.

While cutting tools were being improved the manufacturers of machines for cutting were not standing still. The age of the automobile had arrived, with the necessity for production of interchangeable parts from alloy steels. No longer was machining limited to plain carbon steels. This situation was brought to a sharp focus with the advent of mechanized warfare. For example, some of the gun lathes at Watervliet arsenal at the beginning of World War I had been built previous to 1870. The Government's purchasing agents had not learned that machines which had been suitable for cutting carbon steels would be inadequate for nickel steel. Immediately began a series of disasters to the cutting machines and greater disasters to the cutting tools, caused by deflections and vibrations in the cutting

machinery. Failure of the machines was readily recognized by their inability to hold proper tolerances, but the causes of tool failures were quite obscure — indeed they are still not fully recognized and understood.

The studies on the art of cutting metal, started by Taylor, continued as additional problems arose, and much was learned by day-by-day experiment. Some special testing instruments were devised, but it was very difficult with cut-and-try methods to obtain sufficient data. There was but limited control, not only of the experimental machine setup, but of the uniformity of the test log and of the tool materials, their heat treatments, and the man-made setups. Matters are in reality exceedingly complex. For example, take the punching of thin sheets. Here the problem can be divided up into no less than four groups of variables, 32 in total number:

(a) **Material** — In material there are five distinct items: Composition of material being cut; the processes being applied to that material; the control of the material at mill and factory; the lubrication applied; and the forms of coatings used. (Note that some of these, in turn, are exceedingly complex — for example, metallurgical control in the steel mill!)

(b) **Dies** — Under dies we have 12 items: Designed clearances for different thicknesses of materials; the actual clearances; means of inspection of clearances; the designed cutting capacity; the actual cutting capacity; the inspection of cutting capacity; the material of the die; the hardening processes used on the die; the inspection of results; means for stripping; theoretical depth of penetration; selected point of grind.

(c) **Equipment** variables are seven in number: Condition of the press (its age and the physical accuracy of guides and other related items); foundation; speed of stroke; the actual capacity as measured by deflection; the working capacity as measured by deflection limits; the feeding mechanism; the actual depth of penetrations of the tool for different thicknesses of sheet being cut.

(d) **Management** items are also seven in number: Proper centering of punch and die; proper arrangement of bolts for holding tools and to prevent straining; the proper strength and hardness of bolts, washers and clamps, to prevent movement; safe loading (that is, limiting the press to its deflection capacity); flatness of the bolster; parallelism of bolster and ram, in both loaded and unloaded condition; cleanliness, or the elimination of fine shreds, scale and chips from punch and die as well as the grease, oil and dirt from the setting-up operations.

This seems a formidable list, and may well explain what sometimes appears to be a snail's pace in machinery progress. However, the high speed camera has helped greatly to show the behavior of machines, tools and work in punching, cutting, milling, and similar operations. Many of our preconceptions have been disproved. Such pictures gave the first indication that *vibration* is of the greatest importance — although this might have been suspected 10 years ago when reports started coming in about carbide tools whose edges broke down without any apparent cause. The discovery that high frequency vibrations could be the cause went a long way to improve the situation, for much stiffer machines were built.

This very problem — disintegration of tool edges through vibration — is in fact now used as a cutting means in itself.

IMPROVEMENT OF MACHINABILITY

It has been known for a long time that heat will generally make a metal softer and more pliable and easier to cut, but it is only of late years that thought has been given to the full range of temperature from near absolute zero to the melting point. Generally the tool itself should be cool; use of temperature applies to the material being cut.

The first success in improving machinability through changes in the metallurgy of the materials being cut, *at the instant of cutting*, will probably begin a new era in machining, processing, and finishing. We have hardly gotten started down this road. Our metallurgical brethren in the brass industry were ahead of the procession when they started tailoring a product to fit the needs of the machine shops. Thus they met the demands of two mass production industries prior to the advent of Henry Ford's automobile. I refer to the clock and watch industry, and to the manufacture of screws. Steel users early found that cold drawn bars cut a lot easier than hot rolled bars of the same analysis. Then sulphur and phosphorus were added to the chemical composition to improve machinability even further. How-

ever, all but a few brave men here and there resigned themselves to the supposed truism that parts should be cut from "soft" stock, and the "finished" part then further finished by heat treatment — quench and draw, or case hardening. (These conventional processes have but recently been augmented by such treatments as nitriding, carbonitriding, chromizing and siliconizing.) The brave souls mentioned just above took the attitude that anything could be cut, and so achieved some remarkable performances by operating existing machines and cutting tools in ways that fit the necessities of the parts being cut.

Heat treatment of "finished" parts has become more practical with the advent of atmosphere control. However, let us think for a moment about another aspect of machinabiilty — how to improve the machinability of difficult material by a pretreatment that is evanescent. There is a wide field of opportunity in this direction with the new high-temperature materials. Think of the tremendous field for easy cutting material formed — through addition of gases, coatings, impregnations, and treatments — from alloys that are at present practically impossible to cut.

Another approach is through the machining of materials at other than room temperatures. For example, a very brittle 6% silicon steel will work very well in a punch press if the temperature of the dies and material is raised about 100° C. This is an example of an alloy where a slight temperature change will have a distinct mechanical effect. Other alloys when refrigerated possess different physical properties than when at room temperatures. This can imply several possibilities — for example, a change of phase. One of the most interesting phase changes has been demonstrated by the subzero treatment of austenitic 18-8 chromium-nickel stainless steel; tensile strengths are practically doubled without much change in elongation or ductility. Another example: Some years ago some improvement was obtained in machining the higher manganese steels while held at subzero temperatures.

Herein lies a wide-open field for the practicing metallurgist to apply fundamental facts to shop use.

A new type of cutting tool, seeming to have no counterpart in the past, is the use of high frequency currents. It was probably applied first in the medical field where the surgeon found that searing prevented loss of blood, minimized infection, and did the necessary work in a much shorter time and with less destruction of tissue. Mechanical industry has been slow to catch up with the surgeon. Although there are in use high speed cutting means by heat generation alone, and there has been a recent demonstration of the ability to produce accurate shapes in hard alloys by electron bombardment, there remain to be used combinations of heat and vibration, and vibration through heat and sonic waves. Machine tool designers will have new problems and with them come new needs for the cutting tools.

Mention was previously made of the problem of heat transfer from the cutting edge. If it gets too hot the tool's efficiency is destroyed through the welding-on of particles of the material being cut, or the softening of the tool itself through a tempering action. Carbide materials apparently are more resistant to this welding action than are alloy toolsteels. It would seem, however, that what is really needed is an *insulation* — something in the nature of the layer of phosphates placed on cylinders or tubes for deep drawing to prevent metal-to-metal contact with the drawing dies. (A glass coating has also been applied to tubes for the same purpose.) Many types of wear are really the result of momentary welding where tiny areas of the tool come in contact with the work. To us who always think of welding as an observable heat phenomenon, cold welding must now be recognized. It is the production of energy or an intimate atomic contact, primarily through pressure; it obtains a welding action equal to that obtained by normal heat applied methods.

CONCLUSION

This cursory summary of machining and cutting techniques may open some new lines of thought to metals engineers — whether mechanical or metallurgical — who are not now satisfied with conditions in their immediate field of activity. Possibilities are unlimited! It is good to be alive in such a fast-moving world; it is good to be alive in America where an engineer does not have to check in with a ward heeler for approval before he can safely follow a new idea to its logical end!

By Herbert W. Graham, Vice-President, Technology; Jones & Laughlin Steel Corp., Pittsburgh

Behaviorism of Elements in Iron and Steel Making*

UNTIL RECENT YEARS the metallurgical situation in iron and steel making was quite simple. For two or three decades beginning about 1890 there were very few technical men in the industry other than mechanical and construction engineers. In that period most of the metallurgical progress in America was being made in the universities, under the direction of men like Campbell, Howe, Richards and Sauveur. Metallurgical and other technical work began to increase in the industry greatly in the period of 1915 to 1920 — that is, concurrent with World War I, and in a considerable degree it was due to the urgencies of that war.

At that time chemical investigation in iron and steel plants was limited largely to the analysis of the five common elements: carbon, manganese, phosphorus, sulphur, and silicon. The metallurgist had knowledge of the more common phases of heat treating and a parallel understanding of the simpler aspects of metallic structure as observed under microscopes of moderate resolving power. All the larger plants had testing engineers who knew how to determine the com,non physical properties of steel as required by specifications and for the design and fabrication of bridges and ships. Commercial requirements were simple and concordantly methods of manufacture and fabrication were simple. Even mining methods were simple and beneficiation of raw materials was practically nonexistent. The circumstances of iron and steel manufacture, the methods of fabrication, and the levels of customer requirements and usage of the products were such that raw material quality required no special attention.

Through this period (1890 to 1915) the iron and steel industry, although growing rapidly in size and achieving notable progress in improving its mechanical equipment, got along surprisingly well with what must certainly have been by today's standards a poor and nonuniform level of quality. Nevertheless, by the time of World War I there became uncomfortably evident inadequacies of quality, and difficulties and failures which were largely or wholly impossible to explain by the knowledge of that day. At this point, management began to look for help and naturally turned to one of the newer representatives of technological science, the metallurgist.

In the first few years after World War I (say, in the 1920 decade) the idea existed that the deficiencies of steel in performance and dependability would best be cured by heavy additions of the major alloys such as nickel and chromium. Though this idea originated outside of the steel industry — in the minds of engineering designers, in the growing automotive industry, and in the activities of the ferro-alloy producers — it was necessary for the metallurgist to study the matter intensively. This work included attention to other elements such as molybdenum, vanadium, and titanium. Entirely new information was developed on manganese as an intermediate alloy. Though it did not take long for the metallurgist to learn that increasing the percentage of expensive alloys fell far short of being the entire answer to better steel quality, the years 1920 to 1925 were marked by a great increase of useful information on those grades generally referred to as alloy steels.

In the period of 1925 to 1930 metallurgical science took a great step forward in the recognition of aging, cold work embrittlement, and similar associated phenomena. A degree of control was set up, even though

*The Third Carnegie Lecture, 1951, Pittsburgh Chapter. In his presentation, the author expressed his indebtedness to members of the General Technical Dept. of Jones & Laughlin Steel Corp. for advice on the empirical basis of "recovery" of elements, to various British researchers (particularly Richardson and Jeffes), to Comstock, Urban and Cohen's work on "Titanium in Steel", and to John Chipman for some as yet unpublished information on physical chemistry of steel making.

the causes and mechanism of these phenomena were at first only matters of speculation and hypothesis. Actual proof of the hypotheses is just now beginning to emerge.

Throughout this general period, fabrication by mass production was increasing rapidly. Manufacturers were becoming perfectionists for the sake of decreasing rejections and breakage, and for low fabricating costs. There grew up the idea, again largely in the minds of those outside the steel industry, that the uniformity required by this changing situation could be achieved by narrower chemical limits, particularly for carbon. Today, there are residuals of this idea still existent. But it was not difficult for the steel works metallurgist to see that there were many factors, influential in steel behavior, which were left untouched by even the strictest control of carbon content.

By 1930 there were at least a few metallurgists who began to see that a tremendous part of that personality which is called "steel quality" is related to the influence of surprisingly minute quantities of a large list of chemical elements. New effects were found from previously known elements, and elements that had previously been given no attention were found to be significant. It was also found that the over-all effect of minor quantities tended to be in geometrical proportion rather than merely the arithmetical sum of the individual influences.

From 1930 to the present day, the task of achieving iron and steel quality has been one of steadily increasing complexity. On one hand, more precise fabricating methods and higher level of final requirements constitute more minutely exacting demands. On the other hand, there has been some deterioration of raw materials. In this widening gap, technical problems have become much more difficult, challenging the best combined efforts of geologists, beneficiation engineers, metallurgists, chemists, and plant operating personnel, as well as the vision, understanding, and courage of executives in management.

Iron Making — The materials from which iron and steel are made are (in addition to fuel and flux) virgin iron ores and iron and steel scrap. Being oxides of iron, the smelting of iron ores is simply the removal of oxygen by carbon monoxide. Though this reduction is accomplished at moderate temperatures, it is necessary (even with purest commercially available ores) to carry the temperature of processing upward into the molten phase to slag off the gangue. In melting, the metallic iron absorbs carbon and some part of other metals or nonmetals which have been reduced with the iron.

In simplified terms, the blast furnace operation is a complete and uncontrolled reduction of everything charged into the system which has an energy level or oxide stability less than that of iron oxide, together with the partial reduction of those oxides having a slightly greater energy level than that of iron oxide.

Steel Making consists of preferential oxidation of that carbon in the metallic charge which is in excess of the desired content. The metals and nonmetals which were dissolved in the iron react variously during the period when carbon is being oxidized. In the final stages of carbon elimination the steel bath becomes so pure in iron that mass action comes into play and small quantities of iron are re-oxidized. The final adjustment of steel making is the so-called "deoxidation" of such traces of iron oxide by means of elements specially selected for their avidity for oxygen. This is reduction, delicately and carefully applied.

It may be said, therefore, that steel making is a rather loosely controlled operation of preferential oxidation ended by a brief interval of final reduction.

IRON ORE

Any logical consideration of behaviorism of elements in iron and steel making, as is being attempted in this Carnegie Lecture, must review the present iron ore situation as contributing to the commercial and manufacturing circumstances described in the foregoing introduction, and to examine the metallurgical behavior and influence of elements associated with iron in ores of commercial American usage.

Iron is the second most common metal in the earth's crust, next to aluminum. In fact, aluminum, iron and calcium, in the order mentioned, are the only common metals, all the others being far down the scale in frequency of occurrence.

But iron ore is of commercial importance only when it occurs in huge concentrated deposits of satisfactory purity and availability for reasonably cheap transpor-

tation. Under today's conditions an isolated open pit deposit should contain a minimum of two to five million tons, and if the operation is underground or if new transportation facilities are necessary, a deposit should preferably bulk to twenty or thirty million tons. If large investment is required for concentration mills, then the deposit should be on the order of a hundred million tons or greater.

Such iron ore deposits occur very irregularly, but there are nevertheless few large areas of the earth in which sizable deposits may not be found. They are to be found in considerable number around the perimeter of the Atlantic Ocean as is shown in Fig. 1.

On the western seaboard of the Atlantic Ocean and inland as far as Lake Superior there are many well-known deposits to support the industry of the United States and Canada. There are deposits in Labrador, the Adirondacks, the Lake Superior District, the southern Appalachians (Birmingham), Cuba, Venezuela, and Brazil. Their scattered spread helps support a wide distribution of industry and population.

There is considerable evidence of iron ore in Labrador along a north and south "trough" 500 miles or more in length; exploration in the Burnt Creek area has proved it to be more than 400 million tons. Development of these mines is just beginning, and new transportation of considerable magnitude is required.

In recent years deposits of great commercial value have been proved in Venezuela in an east to west line south of the Orinoco River, some 200 to 400 miles from the sea coast. The first of these deposits is just now being brought into production. The ore exists in great volume and is of good quality. Aside from some necessary political adjustments there are no serious problems except large-scale and expensive railroads, ports and ore barges and sea-going carriers.

Of course our own iron ranges are not completely worked out. In addition there are important deposits in Ontario on the north and east shores of Lake Superior.

As a contribution to the easy and cheap movement of iron ore toward coal, the existence of the Great Lakes waterways is a favorable circumstance that can hardly be overemphasized.

With all the complexities of iron and steel making, it is an interesting and fortunate fact that all commercial iron ores are simply the chemical oxide of iron. There are some mineralogical differences due to a variable amount of water being associated with the oxide. There is also a siderite or carbonate ore, but this is basically an oxide with the loosely held CO_2 radical.

It is further fortunate that iron oxides occur in such huge quantities that these minerals can be the single source of iron. If it were necessary to deal simultaneously with iron phosphide, iron sulphide, iron chloride, and multiple oxides, the ore situation would be commercially and metallurgically much more complicated. This is proved by the fact that the titaniferous ores of New York State and the laterite (nickel and chromium) ores of Cuba and West Africa represent billions of tons of ore almost wholly untouched by industry. It may be that these ores are not simple mechanical mixtures of titanium oxide or nickel oxide or chromium oxide with the iron oxide, but that the titanium and nickel and chromium may, to at least some degree, exist as a part of the iron lattice. If this is

Fig. 1 — Foreign Iron Ore Deposits Around the Atlantic Littoral

true, it shows that the fundamental difficulty is related to true double or triple oxides. In any event, no cheap and wholly satisfactory method has yet been devised to deal with these multiple oxides.

Most iron ores are satisfactory in physical structure, although excessive fineness may require sintering or other agglomeration, and there are a few which are difficult to handle by reason of high moisture content and a sticky, clayey nature.

The nontechnical man and even the geologist and minerals beneficiation engineer find it difficult to understand the emphasis which the plant metallurgist puts on purity of his raw materials. Taking nickel as an example, the question is repeatedly asked: "Since nickel is a valuable alloy in steel products, why is an ore containing nickel not more valuable than an ore not containing nickel?" The question fails to take into account that the unquestionable merit of a given nickel alloy steel requires a certain precise percentage of nickel in relation to the other constituents. Different amounts of nickel are necessary for different uses. When the steelmaker has at hand nickel-free iron and a ferro-alloy of nickel, he can combine the two at will for controlled results. But when iron and nickel come to an iron and steel plant already combined in an ore, it will be only occasionally and accidentally that the combination will match the metallurgical end. In other cases, quality control will be difficult or impossible.

This unfavorable situation exists only in those metals in an iron ore which cannot be separated at reasonable cost from the iron in iron and steel making processes. These metals are those whose oxides have a stability much less than iron oxide. Examples are nickel and copper. Elements with a slightly greater oxide stability than iron, such as manganese and chromium, can be separated from iron and are either only a partial problem or no real problem at all.

For example, the minor elements in a hematite iron ore used by Jones & Laughlin in large tonnage are as follows: Nickel, 0.002%; chromium, 0.001%; vanadium, 0.007%; copper, 0.003%; titanium, 0.077%; zinc, 0.008% and arsenic, trace. Ores high in phosphorus and sulphur are frequently encountered, but there are commercial ways of handling such ores. The magnetites that now are being mined in New York State contain minor percentages of titanium, and here and there ores may contain elements such as arsenic or zinc but, broadly speaking, these do not constitute serious problems.

LOW-GRADE IRON ORES

In the northeastern United States, iron ore is not generally considered commercial with less than 47 to 50% iron, but there are many ores carrying from 20 to 50% in which the percentage of iron can be increased by mechanical treatment (ore dressing or beneficiation). Such procedures vary from simple water washing to highly elaborate mineral separations. The most common problem of beneficiating iron ore is the separation of the oxides of iron and silicon, and the feasibility of any proposed mill circuit depends much upon the fineness of intermixture of these two oxides. There are huge deposits of iron ore, to date largely untouched although within the general range of beneficiation which must be crushed and ground to an average particle size of 100 mesh and downward to 350 mesh to unlock the iron from adhering gangue. These are the gneisses of New York State, the jaspers of Michigan, and the taconites of Minnesota. Only a few of the easier geologic formations (rocks) have been dealt with to date. Bringing them into large-scale usage involves gigantic financial, engineering, and metallurgical problems. But these problems must be solved, and solved they will be. Witness the results achieved year after year with magnetic ores in the Adirondacks (Table I) of lower grade than the Minnesota taconites.

The ease or difficulty of beneficiation will relate in any given ore to the size of that particle which is largely or

Table I — Low-Grade Ores for Beneficiation

Material	Fe	SiO_2	P	S	Al_2O_3
Minnesota magnetic taconite	29.0	46.0	0.10	0.20	1.0
Michigan nonmagnetic taconite	30.0	43.0	0.05	0.10	0.5
Adirondack magnetic gneiss	25.0	41.0	0.20	0.50	5.0
Adirondack magnetite concentrates	62.7	6.3	0.03	0.22	3.0
Adirondack magnetite sinter	62.9	7.2	0.03	0.03	3.3

wholly iron oxide. If the iron-bearing particle size is on the order of 10 mesh or larger, beneficiation will probably be easy and inexpensive, even in physically hard rock. If the iron and silica are locked together in particles of a size on the order of 300 mesh, grinding must proceed to that degree to effect separation, with a greatly increased cost and difficulty. Further, the particles sometimes are in elongated or slab-like shapes rather than spherical and cubical; shape increases the problems of beneficiation.

The accompanying micrograph, Fig. 2, shows the structure of a Michigan jasper; superimposed is a grid which represents a 100-mesh screen. The white grains are iron hematite, the gray grains are silica, and the black areas are cavities. It is clear that separation will require very fine grinding. The point of diminishing returns comes in here. Both investment and operating cost increase rapidly as the particle size becomes smaller. There is the added fact that what is ground to a fine size must be returned to a coarse size by agglomeration before it can be charged into a blast furnace; so it begins to be evident that there will ultimately be reached that point beyond which the mechanical means of ore concentration will not be economical. Beyond that point procedures in the nature of chemical solution would appear to be indicated.

In a blast furnace the upward movement of the blast has a tendency to carry fine material out of the furnace in the gas stream. A considerable proportion of the charge below $\frac{1}{16}$ in. in particle size is ejected as flue dust. In this way the blast furnace acts as a screen or sieve.

Since the blast furnace will not accept a burden largely of fines, the futility of charging fine material has required its agglomeration before charging. Over the past 50 years, sintering of flue dust and fine ore has been used increasingly until today from 20 to 30% of the industry's ore charge is sintered material.

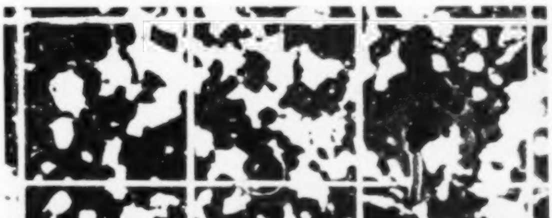
Since sintering increases the cost of ore by about 20%, and since the sinter does not form an ideal blast furnace charge, much attention has been directed to other methods of agglomerating by nodulizing, pelletizing, or briquetting. In general, these methods have not yet been developed to the point of good mechanical operation, satisfactory product, and low cost; but much development work is being done and progress is being made.

The magnitude of this situation is indicated by the fact that the iron and steel industry is today beneficiating something like half its iron ore and this percentage is rapidly increasing. Since beneficiation almost always results in concentrates of fine size, the inevitable increase of agglomerated ore is obvious.

Blast furnace production falls off rapidly and costs increase sharply as the iron content in the ore drops below 50%. Lean ores contain much useless gangue which requires heavy flux additions. Thus, so much of the cubic content of the furnace is required for slag making that the portion remaining for useful iron making is insufficient to support an economic operation. The minimum iron content for economic operation depends upon the type of ore transportation, labor costs, and many other economic factors. Self-fluxing ores are favorable to low-grade operation, and successful practice has been developed in Birmingham, Ala., and in Corby, England, using self-fluxing ore as low as 30 to 35% Fe. In the northeastern United States the economic break-even point is generally considered to require an ore of 47 to 50% iron. Hence, ore below this iron content is not normally used without beneficiation.

In the Pittsburgh District, with non-fluxing ore and with high sulphur coal and coke, it is necessary to operate the blast fur-

Fig. 2 — Mineralogical Structure of Jasper With 100-Mesh Screen Superimposed. White grains Fe_2O_3. (Mitchell)

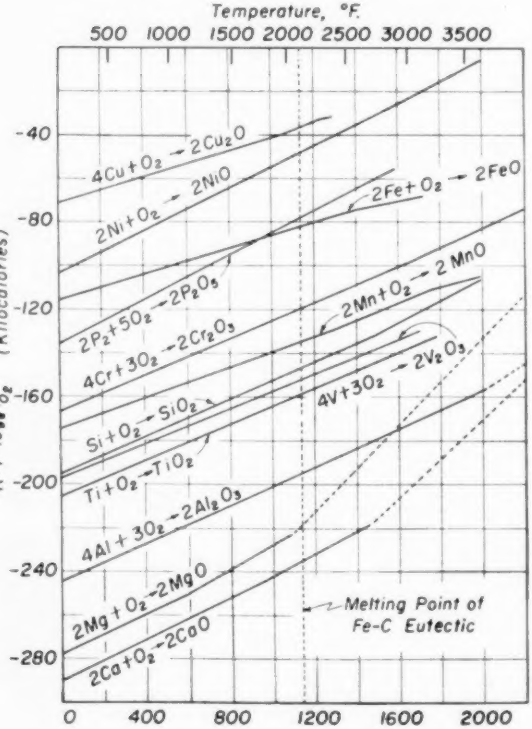


nace with a slag volume of about 900 to 1100 lb. of slag per ton of iron. Hence, as the over-all average iron content of the burden is increased, a point is reached where the natural gangue and its appropriate flux are insufficient to provide an adequate slag volume. Above this point it would be necessary to add siliceous material (such as gravel) with limestone to flux it, in order to maintain the slag volume. Hence, there is a point of diminishing returns for increasing purity of ore.

Because of the many variables involved in the complex operation of blast furnaces, it is difficult to make an exact mathematical demonstration of the optimum iron content for burdens.

Behaviorism of Elements — Much metallurgy in iron and steel works is concerned not with the primary iron but with the behaviorism of other elements. There is a complex interplay in which the elements or compounds change chemically by reaction or physically by solution, diffusion, and by settling and segregration (specific gravity movements).

Fig. 3 — Free Energy of Oxide Formation of Various Elements of Interest in Steel Making, as It Varies With Temperature. Diagram modified from English publication of Richardson and Jeffes



The important characteristic of any element which enters the theater of iron and steel making is its oxide stability. Is the element's oxide more easily reducible than iron, or less easily reducible than iron? Or, having been reduced, will the element reoxidize more easily than iron, or less easily than iron? Both reactions are understood to be taking place in the presence not only of iron but of a considerable number of elements — that is, in a multiple component system — and the word "easily" refers to the energy involved in combination.

The energy released in the oxidation of various elements has been studied by a number of investigators. English workers in this field include Richardson and Jeffes; in this country the metallurgical profession is indebted to much work by Chipman and co-workers, to Comstock, Urban, and Cohen, and to many others.

The diagram shown in Fig. 3 is that of Richardson and Jeffes, modified for easier reading. The authors have constructed a geometrical representation of the free energy of oxide formation in relation to temperature. (This accomplishes a useful visualization at the cost of some accuracy.) The values indicated must be understood to be theoretical. The influence of *time* on reaction is not taken into account, and it is oversimplification to consider a single reaction in a theater in which many physical and chemical reactions are proceeding simultaneously. The oxides Fe_2O_3 and Fe_3O_4 have been eliminated, since these oxides pass through the FeO stage in reduction or oxidation. In steel making, the iron-carbon-phosphorus relationship cannot be followed because oxides of carbon have been eliminated.

Perhaps the greatest difficulty of mentally visualizing or geometrically picturizing reactions in steel making is the fact that they frequently result in a product which behaves in such fashion as to obscure the reaction itself. Often

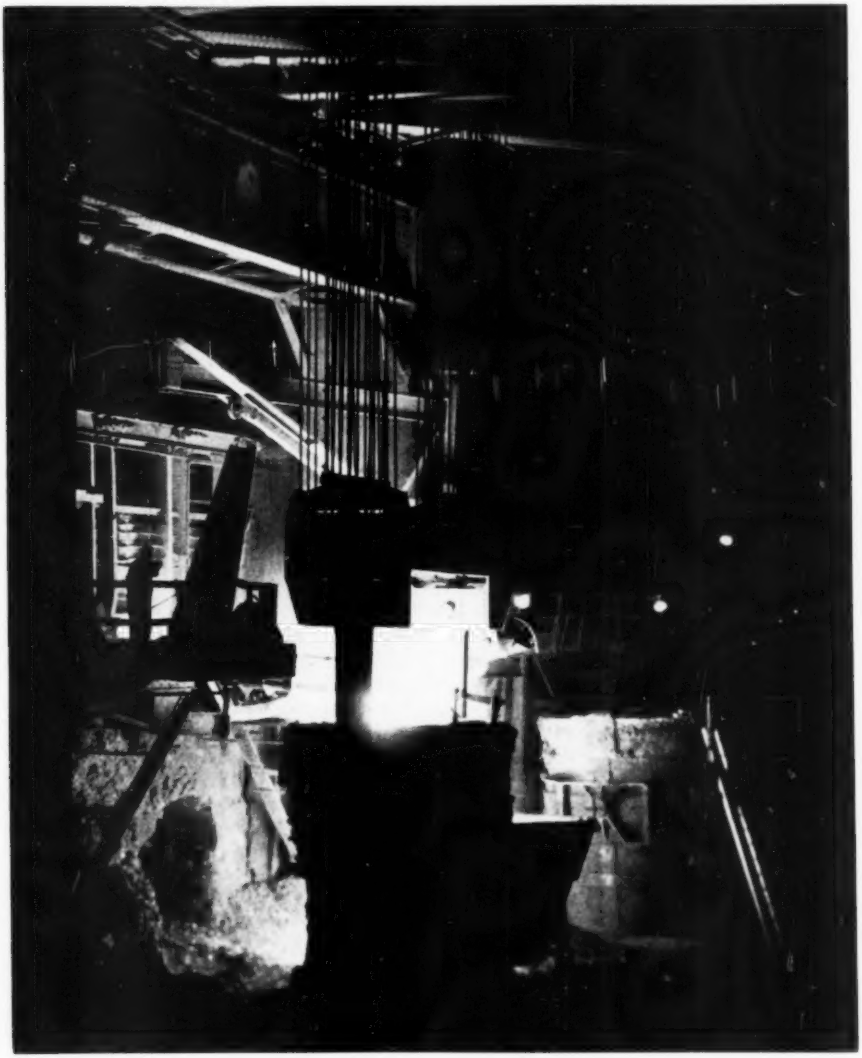
the behavior of reaction products is more important than the reaction.

An example of this situation may be found in comparing the behaviorism of phosphorus and sulphur in a blast furnace. Both elements are lower on the energy scale than iron at temperatures in the blast furnace crucible, and both are completely reduced in the blast furnace, but in behavior after reduction the elements differ greatly.

Behaviorism of Elements

Phosphorus is completely captured physically and chemically by the iron which is undergoing reduction in the blast furnace. The suppliers of raw materials, geologists, mining engineers, and minerals beneficiation engineers will do well to remember that every ounce of phosphorus in the burden will appear in the iron produced. To this

Steel From Openhearth in Otis Works (Cleveland) of Jones & Laughlin Steel Corp.



statement the steel maker and his metallurgist will further attest that phosphorus, though a weak element, is temperamental and annoying and generally contributes to increased costs, to difficulties of control, and frequently to poor quality.

While the exact behavior of sulphur in the blast furnace is not too well known, its very low oxide stability indicates an early reduction with quick formation of iron sulphide. It may be that some of the sulphur exists for a period in the elemental form. If so, it cannot persist in or escape from the system. In its solid form it could not move far down with the stock column before it is gasified. Moving up, it could not escape with the gas because it liquefies at temperatures above that of the furnace top. It is necessary to presume that all of the sulphur in the stock is finally absorbed into the iron, but very fortunately it does not remain there. Every metallurgist and steel maker would shudder at the situation that would exist if all the sulphur of the raw materials were carried into the steel works!

Instead, as slag is formed in the blast furnace, iron sulphide in contact with it is converted into stable calcium sulphide. The result is that about 1% of the raw material's sulphur is rejected in flue dust; there is only a trace in the furnace gas; about 3% of it is physically and chemically dissolved in the iron; and some 96% is carried off in the blast furnace slag. It is possible to effect some further reduction of sulphur in steel making by special treatments.

Empirical Approach — The Richardson-Jeffes diagram is based on the relationships between free energy and temperature, although the general field of complex iron and steel making operations could also be approached by a study of the direct data on heats of formation or vapor pressures. But there is another approach, and that is by examination of empirical data.

Plant metallurgists and iron and steel makers have a long experience from which they know much about reactions and the conditions under which they will or will not take place, and they also have much knowledge as to the behavior of reaction products. They know pretty closely the portion of an element in a raw material which will be captured in a blast furnace and how much of it will be retained under the conditions of steel making. Iron and steel works' personnel do not use the terms "capture" and "retention", but speak of the percentage of an element brought into or held by the metal system as being "recovered".

Table II shows Richardson and Jeffes' calculated values at 2600° F. for a few elements and the empirical knowledge of their recovery from blast furnace and openhearth charges. (Since both operations cover a wide temperature range, particularly the blast furnace, it is virtually impossible to select any one temperature as representative of reaction conditions, so a temperature of 2600° F. has been arbitrarily selected.) Obviously, this table must not be taken too seriously, since the theoretical values are rather academic, and the empirical data are only the loosely assembled observations of experience. Nevertheless, this comparison serves to indicate the placement of a few major elements with respect to the level of reduction in the blast furnace and of oxidation in the openhearth.

The visual character of this situation can be heightened by converting the foregoing table into the diagram shown in Fig. 4. This diagram contains all the errors and shortcomings of the preceding table and must not be taken as a scientific presentation. Nevertheless it visualizes the iron reduction level of the blast furnace and the iron oxidation level of the openhearth, and the behavior of other elements with respect to these levels.

It can be seen that the "energy level" of the blast furnace is about −120 kilocalories. All oxides with energy requirements less than this figure will be reduced, including a major portion of the chromium and manganese in the charge (despite the fact that the energy of their oxides, as shown in

Table II — Energy Compared to "Recovery"

Element	Energy*	% Reduced in Blast Furnace	% Oxidized in Openhearth
Copper	−30	100	0
Nickel	−36	100	0
Phosphorus	−65	100	92
Iron	−75	100 (92)	9
Chromium	−120	90	50
Manganese	−125	70	88
Silicon	−135	14	100
Titanium	−160	5 (35)	100
Aluminum	−185	0	(100)

*Energy of oxide formation at 2600° F. in kilocalories.

Fig. 3, is considerably greater than that of iron). Generally speaking, sulphides act as oxides do. Blast furnace reduction is an uncontrolled, all-embrasive operation. Everything that is weaker than iron will be reduced. There is no trick of control by which operator or metallurgist can prevent the reduction of any given low-energy element. He can do something about silicon, manganese and chromium.

On the basis of data available at this time, it appears that those elements which are entirely reduced to their elemental form in the blast furnace include molybdenum, tin, tungsten, cobalt, nickel, sulphur, antimony, lead, copper, bismuth, and silver. This is not a complete list because data are not available for all elements. But the fact that a given element is reduced does not necessarily mean that it will emerge from the blast furnace system in its elemental form. From the moment of its reduction, characteristics of chemical and physical behavior — as well as thermodynamic influences — come into action to determine whether the element or some new compound thereof becomes a part of the iron or enters the slag.

The openhearth process of steel making has some essential disadvantages but lends itself to metallurgical control. Reagents can be added over a long time and temperature spread, and by adapting conditions to the behavior of important elements. For that reason the product is under a comparatively good degree of scientific control.

SYSTEMATIC CLASSIFICATION

TYPE I	II	III	IV	V
Mo	Cr	Zr	Sb	Hg
Sn	Mn	Al	As	Bi
W	V	Mg	S	Zn
Co	Ti	Ba	P	Pb
Ni		Ca	C	
Cu				

It is possible to classify, broadly and generally, the chemical elements in the raw materials as to their behavior in conventional iron and steel making processes by assembling existing data on oxide stability combined with the best possible summation of empirical experience. Such a classification is attempted in the above table. It applies only to elements as they occur in raw materials as oxides or similar compounds. The classification does not intend to cover those elements in pure form or in ferro-alloys which are introduced intentionally during steel making.

Type I is a group of metallic elements with oxide stability less than iron's. They are completely reduced in the blast furnace and are not oxidized in the openhearth, and hence all of such elements as occur in the raw materials will persist into the finished steel. These elements are mostly beyond metallurgical control and are usually objectionable constituents of raw materials. When added to steel under controlled conditions they have great usefulness (with the exception of tin).

Elements of Type II are of oxide stability slightly greater than iron's. They are only partially recovered in the blast furnace and are more or less completely oxidized in steel making. In general, elements of this group do

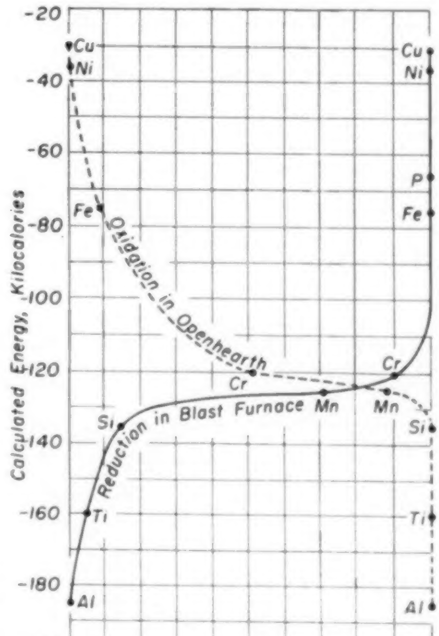


Fig. 4 — Observed "Recoveries" in Blast Furnace (by Reduction) and in Openhearth (by Oxidation) Plotted Against Calculated Energy of Oxidation at 2600° F. Other elements that are practically completely reduced in the blast furnace, in addition to copper, nickel, phosphorus and iron, include sulphur, molybdenum, tin, tungsten, cobalt, antimony, lead, bismuth and silver

not present serious metallurgical problems, although they do have in common the characteristic of unfavorably influencing the properties of slags — as witness the action of titanium in ordinary blast furnace slags.

Elements of Type III with oxide stability very much greater than that of iron, when present in iron ore, are unaffected by blast furnace reduction and accordingly do not carry on into steel making. When present in proper amounts their oxides serve useful slag-making purposes.

As Type IV are grouped nonmetallic and metalloid elements. These elements behave capriciously in iron and steel making, sometimes favorably and sometimes unfavorably, and no single generalized statement could be made to describe the ramifications of their action and reaction. In their behavior are found most of the metallurgical difficulties and problems of the iron and steel industry.

Type V is introduced to be representative of elements that are very reluctant to unite chemically and physically with iron. It is fortunate that they are not commonly found in iron ore, for they are objectionable in iron and steel making systems.

SUPPORT FOR CLASSIFICATION

Since the foregoing classification was rather loosely arrived at, mostly according to oxide stability and element "recovery", a question might arise as to whether there is any scientific justification for such a tabulation. A bit unexpectedly, evidence that the foregoing classification is not entirely random can be obtained by comparing it with the periodic table of elements, as is done in Fig. 5, below.

Type II forms a compact group immediately preceding iron, and Type I (with one or two gaps) follows iron in increasing atomic weight and other properties recognized by the periodic table. In Types III, IV, and V there is quite a bit of scatter in their location on the periodic table. Type III contains alkaline earths plus the light metals and zirconium — all in chemical Groups II, III and IV. Type IV, similarly, are in chemical Group V, with neighbors in IV and VI. Type V are mostly in Series 11. The apparent lack of sequence and correlation in the types suggested is scarcely greater than in the composition of the periodic table itself. Nature has as yet shown no disposition to allow its materials to be neatly pigeon-holed by man according to his ideas of neatness and order.

Comparison of the periodic table and the element classification by types as suggested raises a question as to whether the two are not part and parcel of each other. The simplest conclusion is that, having written a few notations on the periodic chart as to the behavior and oxide stability of some of the elements, it becomes evident that there are groupings of these elements in which the notations are either similar or the notations appear to follow each other in logical sequence. The notations and the group classifications derived from them must therefore be accepted as having some degree of rationality.

It is important to remember that our special notations on the periodic table will necessarily apply to elements in their elemental form. Some of our data, however, relate to circumstances wherein the element is either moving from an oxidized condition by reduction, or to an oxidized condition by oxidation. Such a situation suggests that the periodic table has a thickness beyond that of a piece of paper — a third dimension, so to speak, which has in it the essential conditions of pressure, temperature, and the circumstances of time and motion.

These conditions and circumstances make up the procedure of iron and steel making.

Fig. 5 — Periodic Sequence With Notations Superimposed as to Behavior in Iron and Steel Making

Series	O	I	II	III	IV	V	VI	VII	VIII ←Groups		
1		H									
2	He	Li	Be	B	C	N	O	F			
3	Ne	Na	Mg	Al	Si	P	S	Cl			
4	A	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni
5		Cu	Zn	Ga	Ge	As	Se	Br			
6	Kr	Rb	Sr	Y	Zr	Cb	Mo	Ma	Rh	Ru	Pd
7		Ag	Cd	In	Sn	Sb	Te	I			
8-10	Xe	Cs	Ba	La		Ta	W	Re	Ir	Os	Pt
11		Au	Hg	Tl	Pb	Bi	Po	Ab			
12	Rn	Vi	Ra	Ac	Th	Pa	U				

Type I *Type II* *Type III* *Type IV* *Type V*

ELECTROMET Data Sheet

A Digest of the Production, Properties, and Uses of Steels and Other Metals

Published by Electro Metallurgical Company, a Division of Union Carbide and Carbon Corporation, 30 East 42nd Street, New York 17, N. Y. • In Canada: Electro Metallurgical Company of Canada, Limited, Welland, Ontario

MANGANESE . . .
Deoxidizer and Toughener for Steel

Manganese is one of the most important alloys used in making steel. It is practically indispensable as a deoxidizer and cleanser for improving the hot-working properties of steels. When used as an alloying element, it makes steel stronger and tougher and it is therefore an important constituent of many structural and engineering steels.

Deoxidizes and Cleans Steel

The effectiveness of manganese in deoxidizing steel was first recognized in 1856, when it was used in the Bessemer process of steelmaking to counteract the bad effects of sulphur; in fact, manganese made this process a commercial success. Today, manganese is used as a deoxidizer and cleanser in the production of nearly all grades of open-hearth and electric-furnace steel, as well as high-grade cast iron.

Research work carrried out recently in ELECTROMET's laboratories at Niagara Falls, New York, has provided new and important information on the value of manganese as a deoxidizer. This work shows that manganese is a more effective deoxidizer than has been previously realized; and that a combination alloy of silicon and manganese is a much stronger deoxidizer than either silicon or manganese by itself. Complete information is given in a report entitled "Solubility of Oxygen in Liquid Iron Containing Silicon and Manganese." If you would like a copy of this report, free of charge, write to the address above.

Improves Hot-Working Properties

By combining readily with sulphur, manganese performs another valuable job, it removes the principal cause of hot-shortness or brittleness—thereby giving steel better rolling and forging properties. In this reaction, the manganese combines with the sulphur to form manganese sulphide, as follows:

$$Mn + FeS = MnS + Fe$$

The manganese sulphide remaining in the steel is a less harmful type of inclusion than the iron sulphide would be, the hot-working properties of the steel are improved.

The weakening and embrittling tendencies of sulphur in cast iron can also be counteracted by the addition of manganese to the cupola charge.

Increases Strength, Toughness, and Wear-Resistance

When used as an alloying element in steel, manganese produces a steel with greater strength and toughness, and there is no serious loss of ductility. Additions of about 13 per cent manganese produce the well-known Hadfield manganese steel. High-manganese steels have exceptional resistance to wear; and consequently they have many applications in engineering jobs. Instead of wearing away quickly under conditions combining severe pressure, shock, and abrasion, these steels actually become harder through use. Thus, they last longer.

Because of the tendency of high-manganese steels to work-harden, they serve industry in important and varied applications. Manganese steel castings, for example, are used for railroad frogs and crossings, rock-crusher parts, steam-shovel dipper teeth, and dredge-bucket lips. The chief applications of manganese steel are in rails used for special service, and light forgings subjected to heavy wear.

Dipper bucket teeth, cast of Hadfield manganese steel, actually increase in hardness under abrasive wear from gravel and rock in construction work — thus last many times longer than those of ordinary steel.

ELECTROMET Alloys

Manganese is produced by ELECTROMET in forms suitable for practically every use of the iron, steel, and non-ferrous metal industry. Some of the ELECTROMET products are listed below. For a complete description of these alloys, write for a copy of the booklet, "ELECTROMET Products and Service."

Alloys of Manganese and Their Uses

Standard Ferromanganese	The product most commonly used for adding manganese to steel for the purpose of alloying or deoxidizing and cleansing.
Low-Carbon Ferromanganese	For adding manganese to steels having a low carbon content, such as stainless steels of the 18 per cent chromium, 8 per cent nickel type.
Medium-Carbon Ferromanganese	Commonly used for making manganese steel containing 1.50 to 2.00 per cent manganese, and in the production of Hadfield manganese steel.
Low-Iron Ferromanganese	For applications in the nickel, aluminum, and copper industries where a low-iron alloy is required.
Silicomanganese	Used by the steel industry as a furnace block; as a deoxidizer; and also for manganese additions, particularly in the production of engineering steels containing 0.10 to 0.50 per cent carbon.
"EM" Silicomanganese Briquets	For adding manganese (with silicon) to cast iron in the cupola.
"EM" Ferromanganese Briquets	For adding manganese (without silicon) to cast iron in the cupola.

Personal Mention

William Adam, Jr.

Noah A. Kahn

William Adam, Jr., a metallurgist who has devoted his entire career to the development and exploitation of electric industrial furnaces, was one of the graduates selected recently by Drexel Institute of Technology (on the occasion of its 60th anniversary convocation) to receive an honorary citation for outstanding work in their professional fields. Mr. Adam, who graduated from Drexel in 1921, took a job with Ajax Metal Co., Philadelphia, after graduation and worked on the development of induction furnaces for the next 10 years. With the formation of Ajax Electric Co. in 1931 he was made vice-president and general manager, the position he now holds. He is responsible for several inventions in the furnace field, including basic patents of the electrode-type salt bath furnaces. He is a sustaining member of ASM's Philadelphia chapter, past-president of the Industrial Furnace Manufacturing Assoc., and a member of the Franklin Institute, the American Electrochemical Society and the Wire Assoc. At present Mr. Adams is serving in an advisory capacity on the shell committee of the American Ordnance Association and on the National Production Authority's advisory committee for the furnace industry.

Noah A. Kahn, head of the metallurgy branch, material laboratory, N. Y. Naval Shipyard, has recently been elected president of the Society for Non-Destructive Testing. Mr. Kahn, one of the leaders in the field, has long been active in the Society's affairs, having been a charter member of its New York section. He pioneered in the application of radium radiography, and realized very early the potential value of this inspection tool for both the Navy and for industry. Mr. Kahn graduated from Lehigh University in 1922 with a degree in chemical engineering, and obtained his M.S. degree from Washington University in 1927. From 1922 to 1926 he was associated with Bethlehem Steel Co. as a research metallurgist, entering the naval service in the N. Y. Naval Shipyard in 1927 as shipyard metallurgist. He was subsequently appointed metallurgist in the material laboratory, and helped to organize the metallurgy branch of the laboratory, which, under his direction, has made many outstanding contributions in the fields of welding, casting and foundry practices, physical metallurgy and spectrography. Recently he has been active in investigations relative to the phenomena of brittle fractures in ship plate.

Herbert Ende, Jr., has been appointed Milwaukee branch manager for the Crucible Steel Co. of America. He has been a sales engineer for the company for the past five years.

Thomas N. Peck, director of the aluminum alloy division of the Vanadium Corp. of America, has been appointed deputy director of the aluminum and magnesium division of the National Production Authority, U. S. Department of Commerce.

Adolph Scheid, vice-president and metallurgical engineer, Columbia Tool Steel Co., Chicago Heights, Ill., has left on an extensive South American business trip for the company.

John L. Walter has accepted a position as metallurgical engineer on test assignment for the General Electric Co., Schenectady.

Hugh Baker is presently employed as a metallurgist in the testing laboratory of the Magnesium Division, Dow Chemical Co., Midland, Mich.

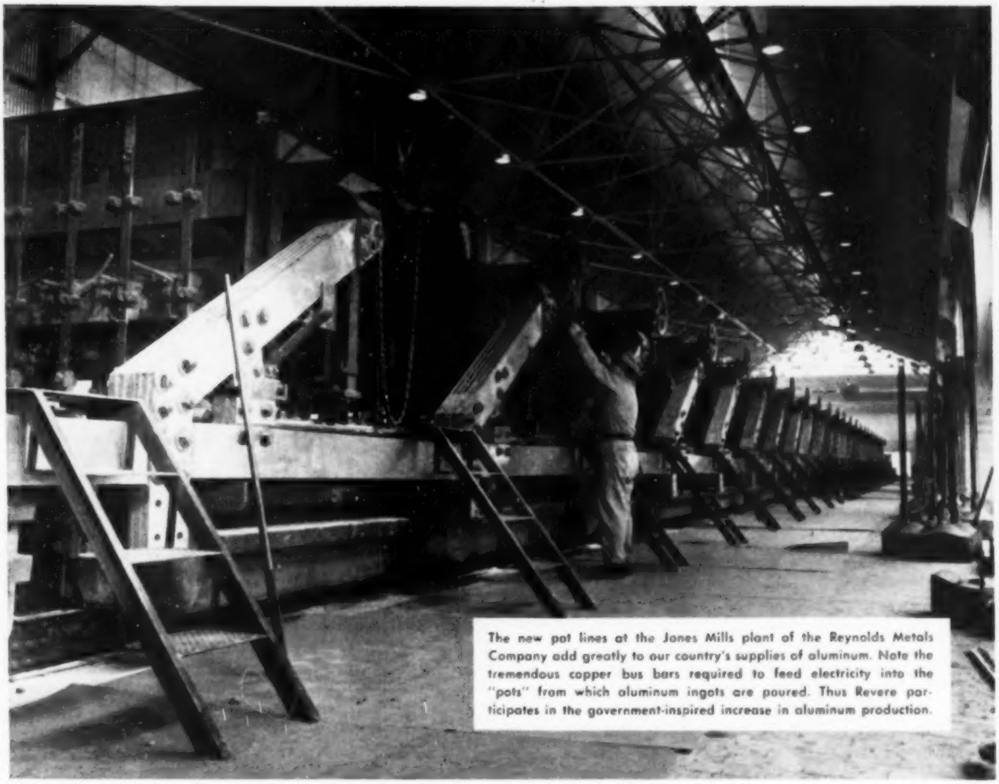
D. I. Sinizer has resigned from his position on the faculty at Massachusetts Institute of Technology and taken a position with Arthur D. Little, Inc., Cambridge, Mass.

Edward J. Rupert has recently accepted a new position with Ipsen Industries, Inc., Rockford, Ill.

George H. Found has resigned his position as manager of the technical service and development division, magnesium department, Dow Chemical Co., to become executive vice-president and general manager of Saginaw Bay Industries, Inc., Bay City, Mich., a firm he helped to establish in 1946.

Robert J. Anderson has left the light metals division, National Production Authority, to join the Southwest Research Institute, San Antonio, Tex.

George C. Floyd, formerly vice-president of Thomas Steel Co., Warren, Ohio, has been elected vice-president of the Vanadium Corp. of America, New York.



The new pot lines at the Jones Mills plant of the Reynolds Metals Company add greatly to our country's supplies of aluminum. Note the tremendous copper bus bars required to feed electricity into the "pots" from which aluminum ingots are poured. Thus Revere participates in the government-inspired increase in aluminum production.

It takes a lot of REVERE COPPER BUS BAR to increase aluminum production

● The Government has directed Revere to produce millions of pounds of copper bus bar for the new aluminum plants being put into operation in order to increase the output of this light metal that is so essential to defense. Copper is the ideal metal to carry the heavy currents required for the "pots" that produce aluminum from the ore. Thus aluminum and copper are intimately linked together. Aluminum is used in planes, ships, weapons, missiles, ammunition, and in many other defense applications. Copper, best of all the commercial metals in electrical conductivity, likewise has many vital tasks to perform for our armed forces, afloat, ashore, and in the air.

Revere is glad that its large capacity for the production of bus bar is so valuable in these times; in our long history of over 150 years of service we have always given everything possible in times of our country's need. However, we are regretful that today's government requirements materially limit our ability to fill civilian orders. We look ahead, eagerly and hopefully, to the time when the present urgent demands are met to such an extent that orders for bus bar and other Revere products can be filled more promptly.

REVERE

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Founded by Paul Revere in 1801

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Personals

James M. Kennedy ⊕, formerly vice-president of the Rome (N. Y.) division of Revere Copper and Brass, Inc., has recently been elected president of the company.

Carl L. McVicker ⊕, formerly openhearth metallurgist at Algoma Steel Corp., Ltd., Sault Ste. Marie, Ont., is now a representative in the Chicago area for Exothermic Alloys Sales and Service, Inc.

Mel Schwartz ⊕ is presently employed by the Bureau of Mines at College Park, Md., in the metals recovery and refining section on a research project.

Frank M. Sito ⊕ has formed a new commercial steel treating company, the Modern Steel Treating Co., Bloomfield, N. J.

Frank Talarico ⊕ is now president of the Bond Metal Finishers Ltd., Montreal, Quebec, a newly formed company specializing in custom hot dip galvanizing.

Charles M. Jones ⊕, who graduated from West Virginia University in June 1951, is now employed as a junior industrial engineer in the coke works of American Steel and Wire Co., Cleveland.

Theodore Cieszko ⊕ has been employed in the engineering department of United Air Lines, Mills Field, San Francisco, since his graduation from the University of California in June.

C. E. Lacy ⊕ has been transferred within the General Electric Co. from the Hanford works, Richland, Wash., to Knolls Atomic Power Laboratory, Schenectady, N. Y., where he is a research associate in metallurgy.

W. N. Miner ⊕, formerly employed by Iowa State College in the Ames Laboratory of the Atomic Energy Commission, has recently joined the Los Alamos (N. M.) Scientific Laboratory as a staff member.

Glenn W. Oyler ⊕, formerly research engineer at Aluminum Research Laboratories, New Kensington, Pa., has recently accepted a fellowship for graduate study in arc welding, sponsored by Linde Air Products Co. at Lehigh University in the metallurgical engineering department.

Richard R. Simonovich ⊕, who recently graduated from the University of Wisconsin, is now employed in the Rockford (Ill.) works of the J. I. Case Co. as a cupola foreman.

Richard R. Studor ⊕ has recently been employed as a metallurgist by Battelle Memorial Institute, Columbus, Ohio, where he is working on cast light metals and alloys.

Charles O. Smith ⊕ received the degree of Ph.D. in metallurgy at Massachusetts Institute of Technology in June. Concurrently with graduate work there, he had been assistant professor in mechanical engineering. Since then he has been employed by the Aluminum Co. of America as a research engineer in the New Kensington (Pa.) research laboratory.

Richard W. Hanzel ⊕ has been employed as assistant metallurgist with the Armour Research Foundation of the Illinois Institute of Technology, Metals Division, since graduation from Michigan College of Mining and Technology last June.

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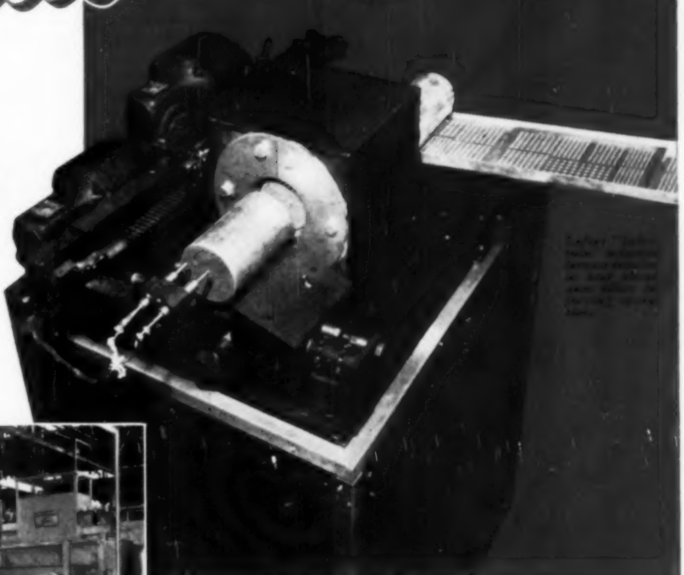

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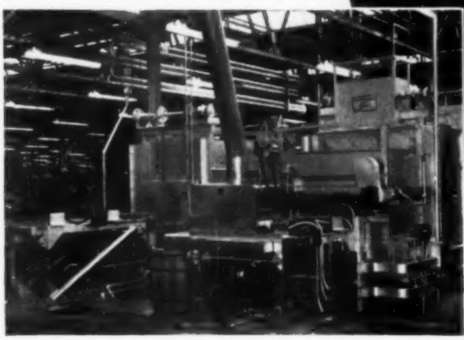

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Personals

Robert J. Sahr has been appointed metallurgical development engineer for the Silver Engineering Works, Inc., and Silver Steel Corp., both located in Denver, Colo. He was formerly night plant superintendent for Heppenstall Co., Pittsburgh.

R. R. Douglas has recently been made assistant plant manager at the Bevil Co., Los Angeles.

Francis J. Herman, formerly assistant openhearth superintendent at Sharon Steel Corp., Sharon, Pa., has been promoted to openhearth superintendent.

Sherman R. Lyle has been appointed district manager of the steel and tube division, Northern Pennsylvania and New York State District, for the Timken Roller Bearing Co.

E. L. Roth, of Motor Castings Co., West Allis, Wis., has recently been elected president of the Gray Iron Founders' Society.

J. S. Houston has been employed as engineer in charge of the works laboratory of General Electric Co., Scranton, Pa., since he received his M.S. degree from Lehigh University last June.

B. Dean Bowen has taken a position as junior engineer with Hot Point, Inc., Chicago, where he is working in the jet engine parts plant.

Kenneth F. Packer, formerly with the metallurgical department, American Brake Shoe Co., Mahwah, N. J., is now an instructor in the production engineering department of the University of Michigan.

Walter W. Offner, president of X-Ray Engineering Co., has moved with the office and laboratory to new facilities built for the company in Mill Valley, Calif.

John J. Shigley has been promoted from principal analytical chemist at the Fort Wayne (Ind.) works of International Harvester Co. to assistant works metallurgist of the company's Springfield (Ohio) works.

Paul H. Anderson has accepted a position as instructor at the Colorado School of Mines in the department of metallurgical engineering teaching iron and steel production.

Wade C. Wurtz, who graduated from the Missouri School of Mines last June, has accepted a position as metallurgist in the materials engineering division of Deere & Co., Moline, Ill.

J. McClure has been appointed manager of quality control at Consolidated Vultee Aircraft Corp., Fort Worth, Tex., and **John M. Thompson, Jr.**, past chairman of the Society's North Texas Chapter, and **Fred E. Stanley** have been promoted to supervisory positions in the process control section of the quality control department of the same company.

Chin Tse Yang has left the University of California to accept a position as assistant professor of mechanical engineering at Massachusetts Institute of Technology, Cambridge, Mass.

Edward S. Wright, formerly with the Atomic Power Division, Westinghouse Electric Corp., has accepted a position as research assistant at the Los Alamos (N. M.) Scientific Laboratory.

Personals

The Park Chemical Co., Detroit, has announced the following appointments as sales representatives for their heat treating division: **A. T. Ridinger**, Industrial Electro-Gas Equipment Co., Minneapolis, for Minnesota and Iowa; **M. K. Griggs**, Houston, Tex., for the state of Texas; and **Hugo W. Hiemke**, of the California Alloy Products Co., Pasadena, for the state of California.

Carl C. Osgood has resigned as associate in mechanical engineering at the University of Pennsylvania and accepted a position as mechanical engineer in the analytical group of advanced development section of RCA Victor, Camden, N. J.

Edwin D. Howell has been appointed assistant manager of the Rome (N. Y.) manufacturing division of Revere Copper and Brass, Inc. He was formerly works manager of the company's Clinton (Ill.) manufacturing division.

Raymond J. Towner has been employed as a research metallurgist with the Aluminum Research Laboratory, New Kensington, Pa., since his graduation from Rensselaer Polytechnic Institute last June.

William F. Eberly has been transferred from the Latrobe, Pa., office to the Philadelphia office of the Vanadium-Alloys Steel Co., where he is a sales representative.

Nicholas Sheptak, who graduated from Cornell University in June, has been employed since that time in the magnesium department, Dow Chemical Co., Midland, Mich., as a research and development engineer.

H. E. Cragin, Jr., formerly plant and foundry superintendent, Taylor-Wharton Iron & Steel Co., High Bridge, N. J., has been transferred to the company's Cincinnati laboratory where he is director of research and development.

Raymond O. Deneen has been employed in the engineering section of the Radio Corp. of America in the Lancaster, Pa., plant since his graduation from West Virginia University.

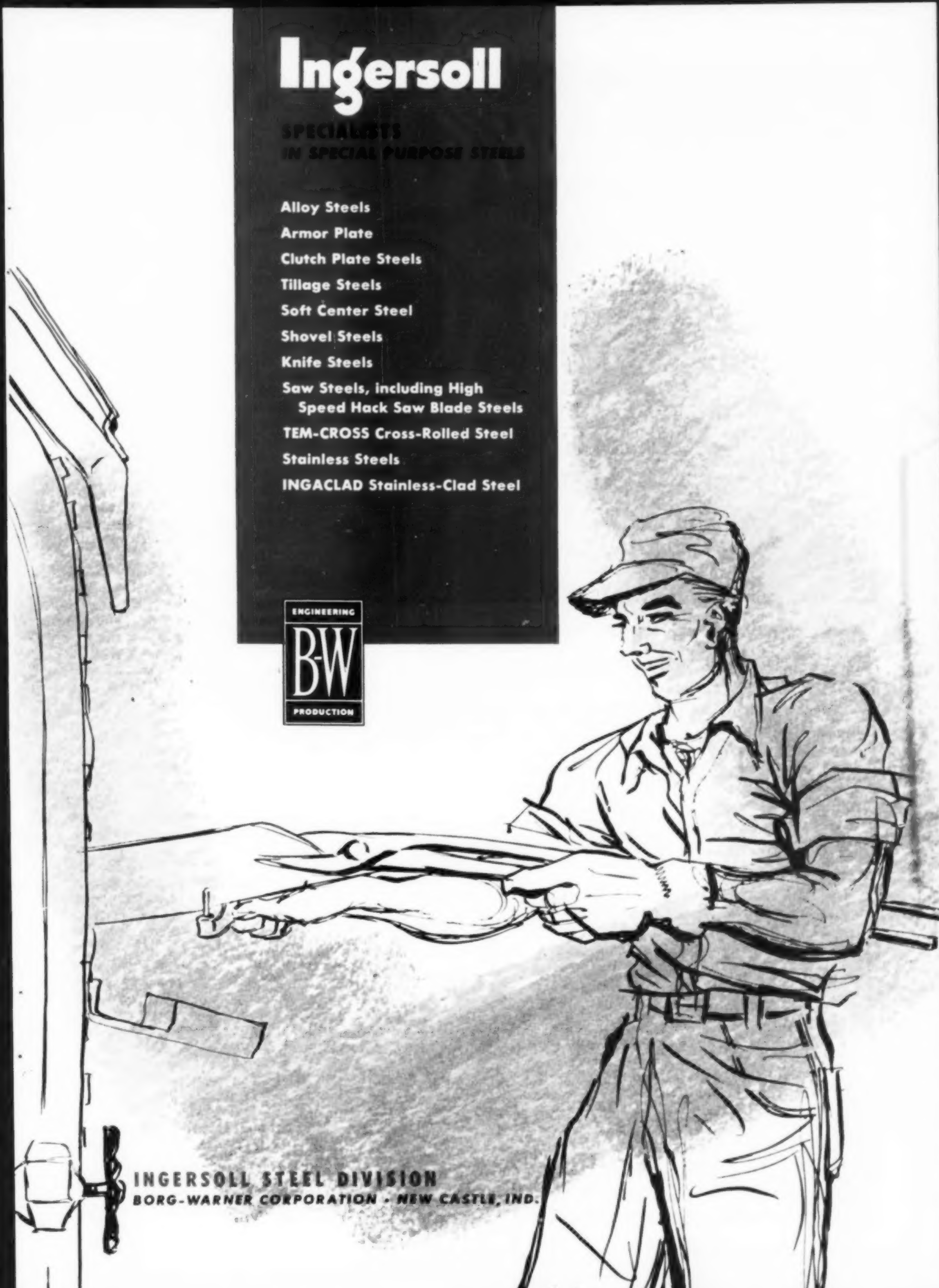
Karl W. Reber and **Russell C. Nelson** have been appointed associate engineer and chemist, respectively, on the technical staff at Union Carbide and Carbon Corp.'s Oak Ridge National Laboratory, Oak Ridge, Tenn.

Joseph R. Driear has been employed at E. I. duPont de Nemours' Argonne National Laboratory since receiving his M.S. degree from the Colorado School of Mines last June.

William G. VanNote has left North Carolina State College, where he was director of the department of engineering research, to assume the presidency of Clarkson College of Technology in Potsdam, N. Y.

A. J. McAllister has been appointed president and general manager of the Detroit Gear Division, Borg-Warner Corp. He was formerly president and general manager of the Fairfield Manufacturing Co., Lafayette, Ind.

Boyd E. Cass was recently named manager of metallurgical sales for Foote Mineral Co., Philadelphia. Prior to assuming his new position he served as sales engineer to the metallurgical trade for the company.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Heat Treatment in Magnetic Field

METALLURGISTS of the old school may remember the flurry in heat treating circles caused some 20 years ago by an announcement by E. G. Herbert in *Journal* of the Iron and Steel Institute that steel, duralumin and other alloys, hardened by conventional heat treatments, could be further hardened by rotating them in the field of a powerful electromagnet. For example, increases from 700 Brinell as heat treated to 820 after magnetic "aging" was reported for steel. *Metal Progress* in 1932 had no less than eleven communications on this matter. Suffice it to say that neither American nor English metallurgists were able to secure such results as published by Mr. Herbert; in fact no measurable differences appeared after the Herbert treatment.

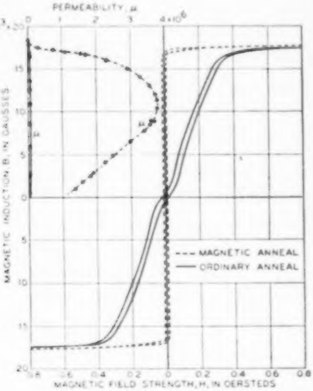
Indentation hardness (tensile strength) and magnetic "hardness" and other properties are quite different families of properties, however. Heat treatment while the piece is in strong magnetic fields will make quite appreciable changes in magnetic properties, when compared with measurements made on identical samples of identical history except that heat treatment was done with no imposed field. The brief paper mentioned in the footnote* is an example.

If a series of iron-silicon alloys be tested for permeability after annealing 1 hr. at 1830° F. in vacuum, the magnetic permeability of all samples up to 11% silicon is about 12,000 (a small peak of about 25,000 is shown at 6.4% Si). A more prominent peak at the same composition ($\mu = 55{,}000$) is found if the samples are annealed in hydrogen at 2375° F. for 120 hr. However, the latter treatment plus a re-anneal at 1300° F. in a magnetizing field of 10 to 12 oersteds will increase the maximum permeability of the 6.4% Si alloy to over 200,000. This material reverts to its former state after annealing again at 1200° F. in zero field.

The above figures are for commercial iron-silicon alloys. When special attention is given to the purity of the constituents, permeabilities of 500,000 have been achieved. At 6.4% Si all iron's allotropic transformations are eliminated, so that high annealings cause no recrystal-

*"Iron-Silicon Alloys Heat Treated in a Magnetic Field", by Matilde Goertz of Bell Telephone Laboratories, *Journal of Applied Physics*, July 1951, p. 964.

lization. Heat treatment in a magnetic field at 1300° F. corresponds to the Curie temperature (varying from 900 to 1420° F.) of the alloy. This composition is about that for zero magnetostriction, and also near where atomic ordering begins to be detectable by X-ray diffraction analysis.



A single crystal of 6.5% SiFe was also investigated. The figure shows that after long anneal in hydrogen the maximum permeability in the [100] direction of easy magnetization was 50,000. After annealing 1 hr. at 1300° F. in 12 oersteds the maximum permeability was 3,800,000, the highest value yet reported for any material. The figure also shows the hysteresis loops in the two conditions; magnetic annealing squares this loop remarkably. Subsequent heat treatment at 1200° F. in zero field caused the crystal to revert to its original properties. E. E. T.

Sintering Iron Ore in England*

A JOINT INVESTIGATION of the sintering of Northamptonshire ores was conducted on a laboratory basis under the auspices of the British Iron and Steel Research Association and in the Corby Steel Plant of Stewarts & Lloyds, Ltd. In view of the great interest in the United States at the present time in the sintering, pelletizing or other agglomeration methods for compact-

(Continued on p. 108)

*"Investigation of the Effects of Controlled Variables on Sinter Quality", by E. W. Voice, C. Lang and P. K. Gledhill, *Journal*, British Iron and Steel Institute, Vol. 167, April 1951, p. 393-439.

Sintering Iron Ore in England

(Continued from p. 107)

ing fine ore dressing products and flue dust, this thorough study of sintering should be of value to American blast furnace engineers and metallurgists.

The raw materials being sintered at this plant consist of mixed fines from the ore bedding piles, run around sinter fines, blast furnace flue dust and coke breeze. The ore fines are mixtures of siliceous hydrated hematites and carbonate (siderite) stone and have a composite analysis of:

Fe (total)	SiO_2	Al_2O_3	CaO	H_2O
29.2%	8.3%	6.2%	5.7%	17.0%

As this ore is similar to the East Texas ores now being processed at Daingerfield, Texas, and also resembles the Birmingham, Alabama, red ores, the sintering problem at these points has many similarities to the conditions described in this investigation.

The laboratory study of the controlled variables was carried out on a specially designed single pallet with a 4-ft. grate area, an igniter to permit variation in igniter fuel and amount of suction and equipment for testing the experimental sinter cakes for strength, porosity, dust loss, and similar factors.

The important factors influencing sinter quality which were studied in the laboratory were *(a)* suction control, *(b)* amount of fuel (coke breeze), *(c)* percentages of returned fines and flue dust in the sinter mix, *(d)* size of ore fines and coke breeze in the mix, *(e)* methods of mixing the raw materials before sintering, *(f)* moisture content of mix, and *(g)* types of fuels used for sintering.

The laboratory studies led to the following conclusions:

1. Sinters produced on the small test unit showed good correlation with the sinters obtained on the large plant machines.

2. The percentage of coke breeze in the mix was the most important factor governing the efficiency of sintering. The optimum percentage was found to be 6%. The use of greater amounts of carbon had no beneficial effect; smaller amounts led to incomplete sintering.

3. At a fixed coke content, increasing flue dust in the mix improves sinter quality. The carbon

(Continued on p. 110)

Sintering Iron Ore in England

(Continued from p. 108)

in flue dust (10 to 15%) is about 60% as effective as the carbon in the coke.

4. At a fixed coke and flue dust ratio, increasing the return sinter fines in the mix improves sinter quality.

5. Increasing suction decreases sintering time; sintering time is inversely proportional to the logarithm of the suction.

6. Water contents between 14 and 18% were best, with an optimum of 18% moisture.

7. Degree of fineness and thoroughness of mixing of the raw materials was found to be very important.

8. Quality of sinters could be measured by a dust index and a strength index.

9. Variation of type of fuel used for sintering showed no advantage over coke.

Investigation of full-scale operations at the Corby plant, applying the principles established in the pilot plant, indicated that the factors most important in regulating sinter quality were:

The effective carbon content of the mixture, the size of the coke breeze (preferably under ⅛ in.) and the uniformity of the carbon distribution in the mix. It was found that mixtures with 6 to 6½% effective carbon with the coke breeze crushed to under ⅛ in. size gave best results.

The mixing and size distribution of the four raw materials was found to be next most important. Feeding of the desired ratio of the various ingredients led to lack of uniformity in mixing and poor sinter. Mixing of the combined feed was tried in trommels, revolving drums, hammer mills and a system of hoppers. The hammer mill mix was superior because it yielded a finer mixture and a greater probability that a particle of fine coke would be adjacent to an ore particle. Size of ore particles should be under ¼ in.

The use of return sinter fines in proportions of 10 to 30% of the mix had important effects. If the fines were mixed with the rest of the charge in the hammer mill, the quality of the sinter was the best produced. The diversion of returned sinter, screened to +⅜ in. and deposited separately on the

(Continued on p. 112)

Sintering Iron Ore in England

(Continued from p. 110)

grates to a depth of 2 in. before the fine sinter mix was charged, was also highly desirable in protecting the grates, lowering dust loss, and improving the efficiency of the sintering.

The control of ignition and water content were significant and also interdependent. With other factors favorable, a water content of 15% was desirable, but much higher moisture could be tolerated with accurate fuel and ignition control. E. C. WRIGHT

Blast Furnace Sinter*

THE PAPER is based on a recent survey of sinter plants conducted by the A.I.S.I. subcommittee on Agglomeration of Fines. A large fund of information was collected. This background, along with results of past experience, forms the material for the discussion. Several reports prepared during the period between 1938 and 1943 showed promise that benefits could be derived from the use of sinter. They indicated coke savings of 9 to 16%, production increases of 6 to 20% for burdens containing from 30 to 85% sinter.

In 1947, a carefully conducted test at Edgar Thompson Works proved that the benefits, increased production and decreased coke rates, were due to the use of sized materials. This test was not a test on the effects of sinter alone, since a burden containing 20% sinter and the remainder, coarse screened ore and concentrate, was compared with a normal unscreened burden. Within the limitations of this comparison, however, the sinter used apparently fulfilled the requirements for a sized material and may have contributed to the practice improvements which were obtained.

The survey indicates that not all furnace operators are as enthusiastic in the use of sinter as implied by the older published reports. However, most plants have not made careful tests. Instead, judgment seems to be based upon

(Continued on p. 114)

*Abstract of "Improving Current Practice in Blast Furnace Sintering", by R. E. Powers, a paper presented before the General Meeting of the American Iron and Steel Institute at New York, May 23-24, 1951.


How to get the answers to many of your Metalworking Problems
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Blast Furnace Sinter

(Continued from p. 112)

day-to-day operating results without the advantage of controlled conditions. Operators reported that, in general, results were not as satisfactory as desired. Improvement in a few cases is noticeable upon substitution of sinter for Lake ores, but more often it is unnoticeable or inconsistent. Two plants provide exceptions to these general conclusions. Here sinter forms an integral part of a beneficiated ore supply. The over-all results of sized ores and many other factors are beneficial. Little opportunity has been experienced for operation without sinter.

The normal percentage of sinter in the burden varies from 18 to 65%. In most cases this is governed by the available amount. The sinter is usually split evenly among furnaces or else the amount is controlled by transportation facilities, there being no plant using more sinter on one furnace than on another for reasons of improved performance.

The maximum amount of sinter used at the various plants ranged from 25 to 90%. Some southern furnaces "tightened up" when 23% sinter in a burden of all prepared ores was raised to 33%; other southern furnaces showed maldistribution by "blowing through" when the normal 20% sinter was raised to 50%. There was no indication at any plant surveyed of an optimum percentage of sinter. This is in marked contrast to earlier reports which had shown that the advantages of sinter increased up to a certain percentage and tapered off above that.

The situation at present is confused and complex. Test programs have been tried but results were disappointing because other operating variables obscured the effects of sinter. Several plants connected with one large corporation have been provided with an organization and a staff for making multiple correlation analyses of all plant results, including blast furnace operation. At the time of the survey, work over a period of several months had not produced positive results.

These experiences seem to indicate that sinter, as commonly produced, acts very much like ore of similar analysis and that its chief advantage consists largely in upgrading its iron content.

In plants across the country, all

(Continued on p. 116)

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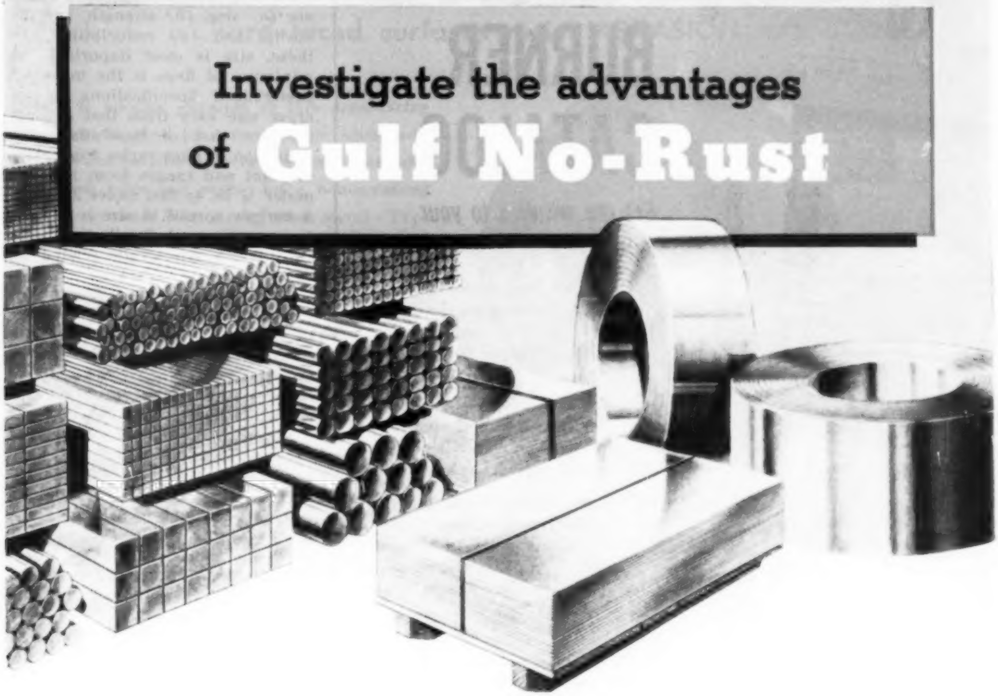

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If your customers report cases of surface spoilage due to corrosion, it will pay you to investigate the advantages of Gulf No-Rust. Ask a Gulf Lubrication Engineer for further details. He will fully inform you on the suitability of Gulf No-Rust for various methods of application, types of metal surface, size of product, length of time for which protection is required, conditions of storage or shipment and ease of removal. Write, wire, or phone your nearest Gulf office today.

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Blast Furnace Sinter

(Continued from p. 114)

kinds of sinter are made: large and small, fused and fritted, hard and soft, strong and weak, iron-rich and iron-poor. Nevertheless, at each plant there exists a lingering doubt as to whether the sinter being used is the best kind.

The properties of sinter most commonly considered important are *(a)* size, *(b)* strength, *(c)* porosity, and *(d)* reducibility. Of these, size is most important. A minimum of fines is the universal preference. Specifications for average size vary from that of popcorn to that of baseballs. The definition of fines varies from plant to plant and ranges from material under ¼ in. to that under 20-mesh. A narrow spread in size is desired to promote good distribution.

Strength is closely related to size and has been proved by laboratory tests to be dependent on the fuel content of the feed mixture. Porosity, as is surmised from the fundamentals of gas contact, is an important factor in the reducibility. Large differences exist, particularly as to distribution of pore sizes.

Swedish authorities lay great stress on oxidation and its effect on reducibility (see "Sinter and Sponge Iron in Swedish Practice", p. 118). The iron present as hematite in Swedish sinter is reported to be about 90% whereas in American sinters it ranges from 9.9 to 46.3%, with the balance present mostly as magnetite.

The survey brings out the need for control tests, developed and standardized to permit intelligent comparison of sinter characteristics and performance at different steel plants.

All phases of sinter production are discussed. Attention is called to the fact that production rates for American plants ranged from 1.95 to 4.08 net tons per sq.ft. effective grate area per 24 hr. compared to 1.7 for German plants, 1.1 to 1.9 for Swedish and about 2.7 for Russian plants.

The summary of data and information collected on such factors as screening ore lime in mixture, mixing, distribution, ignition, burning of bed, return fines, cooling and handling and maintenance create the impression that great improvements are possible. To this end recommendations are indicated for plant design, plant operation, research and development, and blast furnace testing. A. J. HOCH

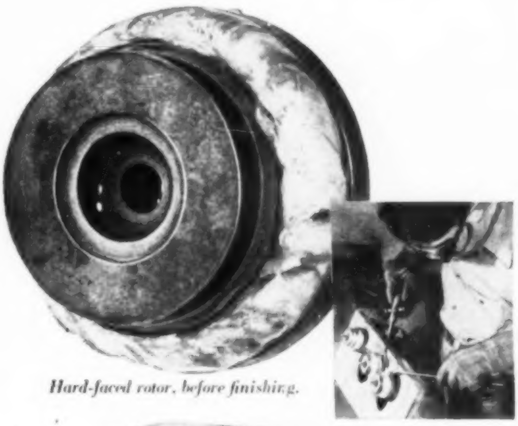
DOUBLES LIFE
OF MIXER PARTS

...tough base metal withstands SHOCK
...hard-faced surfaces resist ABRASION and CORROSION

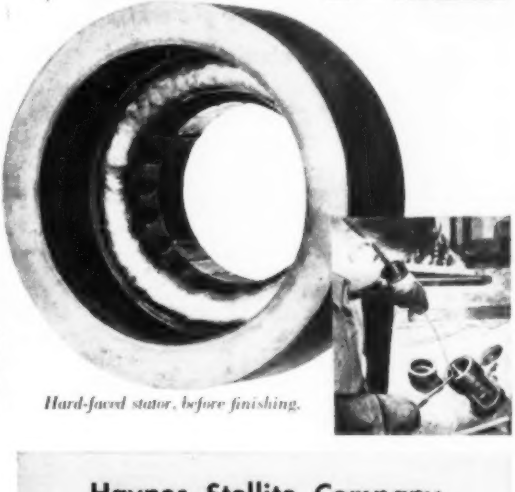
Here is another example of how hard-facing eliminates the need for a compromise when both hardness and toughness are needed for a particular part. This rotor and stator for a homogenizing machine are made from a tough base metal—Type 303 stainless steel. The bearing surfaces of the two parts are hard-faced with HAYNES STELLITE cobalt-base alloy. The parts are tough enough to stand up under the shock of pulverizing operations at high speeds . . . and yet the working surfaces are hard enough to resist the abrasive and corrosive effects of the materials being mixed.

For two years, no machine equipped with hard-faced parts has been returned or serviced because of rotor or stator failure. The heat-treated parts formerly used on these machines failed after only a year's service. The heat-treatment affected the corrosion resistance of the metal and also made the blades on the rotor too brittle.

For the whole story on hard-facing, including detailed procedures for applying various HAYNES alloys to wearing surfaces, write for the new 40-page booklet, "HAYNES Alloys—Hard-Facing Manual."



Hard-faced rotor, before finishing.



Hard-faced stator, before finishing.

Hard-facing doubles the life of these mixing-machine parts. In operation, they run with very close clearance at speeds of at least 3600 revolutions per minute. The clearance between the hard-faced bearing surfaces is filled in with the abrasive mixture.

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Sinter and Sponge Iron in Swedish Practice*

DESPITE THE FACT that Sweden possesses great resources in high-grade, dense magnetite, nearly all its pig iron is smelted from a carefully prepared sinter. Fuel is expensive charcoal or imported ore; the aim is to sinter a high-grade ore mix or concentrate having self-fluxing characteristics, change the Fe_3O_4 to the more readily reduced Fe_2O_3, and produce a structure that is penetrated quickly and easily by the shaft gases. This is known as a "black burned sinter". It is free from glazed surfaces, and has uniform cellular structure, free of large holes. To achieve these characteristics a temperature necessary to frit the particles together must be attained but not exceeded, else glazed or vitrified surfaces are produced. Time at and immediately below this critical temperature must be short. Uniform mixing of the charge, loose and uniform charging, simultaneous and uniform ignition, fine crushing of fuel, and a plentiful air supply are details of sintering practice that must be adhered to rigorously to insure a close control of temperature throughout the bed. The sides of the pan are sloping to minimize channeling along the edges. A loosely packed charge is preferred because it yields a more compact sinter. Moisture content, quantity of fuel and screen analysis must be checked as often as six times per hour.

Batch-type sintering and the use of ore fines or concentrates of fairly uniform screen size are factors that help produce sinter of high quality. The general opinion is that Swedish sinter is considerably weaker than that produced in the United States. Regardless of strength, an important consideration is that Swedish sinter is so handled after it is produced that it normally enters the blast furnace in pieces 2 to 3 in. diameter with relatively small amounts of small sizes. Sinter that must withstand shipping should be stronger than a product made at the furnaces. However, sintering or agglomerating plants should not be built at long distances from the furnaces except after careful consideration of the advantages of a readily reducible product, which can be carefully handled in transit to the blast furnace.

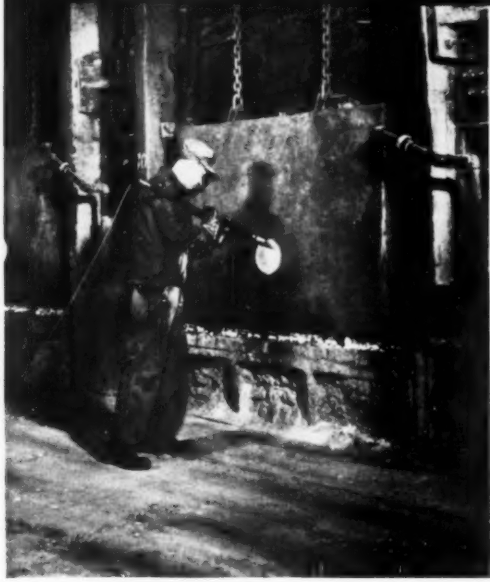
Concentration of iron ore to reduce slag volume and production of

(Continued on p. 120)

*From "Sweden's Iron and Steel Industry", by T. L. Joseph, *Journal of Metals*, July 1951, p. 507.

FOR MORE INGOT TONNAGE PER HEAT

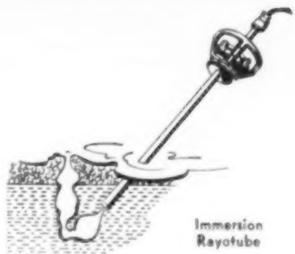
Measure Temperatures By Immersion Thermocouple or Immersion Rayotube



OPEN HEARTH and electric furnace shops can now choose between two tested L&N methods for measuring steel temperatures during the melt. Either an Immersion Rayotube or an Immersion Thermocouple is plunged momentarily beneath the surface to measure the temperature of the bath, while a dependable Speedomax Recorder displays the information where all concerned can use it.

Either method helps improve ingot production by warning if the steel is too hot or too cold for tapping. Recently published talks before national steel associations indicate that production losses have been sharply cut in plants where temperature is properly measured while the melt is finished off for tapping.

It pays to select your immersion-measuring equipment from a source which makes both radiation and thermocouple types. The two equipments cost about the same initially; among the factors which should be weighed without prejudice are: size and type of furnace, type and quality of steel, experience of helpers in using instruments, supervisory set-up and the differences in maintenance supplies and labor. If you'll contact our nearest office, or 4927 Stenton Ave., Philadelphia 44, Pa., we'll be glad to supply such other information as you desire.



Rayotube gets its reading inside a bubble blown by compressed air or other gas, while Thermocouple contacts the metal directly. Both methods give the "heart" temperature of the molten steel, and give it in time for any changes necessary before tapping.

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Sinter and Sponge Iron in Swedish Practice

(Continued from p. 118)

high-quality sinter has led to a reduction in coke consumption in Swedish blast furnaces. Average coke rates have fallen from about 2250 lb. in 1926 to 1930 to a low of 1412 lb. per net ton in 1947. This indicates efficient operation of small units, regardless of high heat losses in the crucible. The use of large amounts of sinter of improved quality has reduced the consumption of fixed carbon more than 10%.

Sweden has been producing sponge iron commercially since 1911 by the Hoganas process. In this process, refractory crucibles filled with alternate layers of solid fuel, crushed limestone, and ore are heated in kilns until the ore layer is reduced to metal that is sintered into a cake. The Wiberg shaft furnace has also been making sponge iron at a toolsteel plant at Soderfors for a number of years, at the rate of about 20,000 tons a year and costs ranging from $26.75 to $35.10 per metric ton of 2205 lb. [P. E. Cavanagh, in *Metal Progress* for May 1950, describes this furnace and estimates it cost under Canadian conditions at $31.37 per ton of 2000 lb.]

It is natural that the feasibility of using sponge iron in the open-hearth, as well as the electric furnace, has been considered seriously in Sweden for the past 20 years because of the shortage and high cost of charcoal pig iron and of high-grade scrap. Moreover, the production of sponge iron requires relatively small amounts of fuel, which need not meet all of the requirements of blast furnace fuel.

Soderfors charges 10-ton arc furnace with 70% sponge iron and 30% home scrap. The Sandviken Steel Co. also used sponge iron in acid openhearth charges for many years. Even the ore for use in the direct iron furnaces may economically be beneficiated.

A porous, light burned sinter is used in the Wiberg sponge iron furnace at Soderfors, but encouraging results have been obtained with pellets, about 1 in. diameter, made in a shaft furnace of the type used by the Minnesota Mines Experiment Station.

At Malmberget a concentrate is produced containing about 71.5% iron, about 0.6% SiO_2 and 0.010% P max. Concentrates containing about 71.7% iron and 0.15 to 0.20% SiO_2 have also been produced for use in

(Continued on p. 122)

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Sinter and Sponge Iron in Swedish Practice

(Continued from p. 120)

the Hoganas sponge iron process. To produce such high-grade concentrates, the ore is ground to fine sizes to liberate the silica. The pelletizing process fits into the over-all picture because it is a means of agglomerating very fine concentrates that would be difficult to sinter.

Under the guidance of Jernkontoret, several companies are participating in a development involving: *(a)* The production of rich concentrates, 68% Fe or higher; *(b)* the agglomeration of these concentrates by the pelletizing process; and *(c)* the reduction of these pellets in a Wiberg shaft furnace.

The incentive to produce high quality melting stock in Sweden is great. Solutions probably will be found to all minor problems and in the end sponge iron may gradually replace charcoal pig iron in the production of Swedish quality steel.

Work Required in the Formation of Martensite Nuclei*

Study of the kinetics of the transformation of austenite to martensite in the temperature range below room temperature has shown that the velocity of transformation is measurable at sufficiently low temperatures and decreases with further decrease of temperature. The temperature dependence of austenite decomposition can be expressed as:

$$\frac{1}{V_0'}\left(\frac{dV}{dt}\right)_{t=0} = A\,e^{-U/RT} \qquad (1)$$

where V is the amount of martensite (determined magnetometrically); V_0' is the limiting amount of martensite that forms at temperature T; A and U are constants of the steel being studied.

Since the growth of martensite crystals is limited, change of V occurs primarily as a result of an increase in the number of martensite crystals; that is, it is determined by the velocity of formation of martensite nuclei.

If it is assumed that the average size of martensite crystals forming

(Continued on p. 124)

*Abstract of "Work of Forming Martensite Nuclei", by G. V. Kurdyumov and O. P. Maksimova, *Doklady Akademii Nauk SSSR*, Vol. 73, 1950, p. 95-98.

Formation of Martensite Nuclei

(Continued from p. 122)

initially is constant, it follows that,

$$\frac{1}{V_o'}\left(\frac{dV}{dt}\right)_{t=0} = nv \qquad (2)$$

where n is the number of nuclei forming in unit time in unit volume, and v is the average volume of a martensite crystal.

Comparing equations 1 and 2 with the formula for the velocity of the fluctuation nucleation of the nuclei of a new phase in the crystallization of a liquid,

$$n = K e^{-U/RT} e^{-W/RT} \qquad (3)$$

(where U is the activation energy, W is the work of nucleus formation, and K is a coefficient that is independent of temperature), it is possible to conclude that the work of nucleus formation, W, is small in comparison with U, and that $K = A/v$. The latter relation permits an estimate of the value of K. Since A, in this case, is of the order of 10^{-2} sec.$^{-1}$, then taking the dimensions of a martensite crystal to be $10^{-3} \cdot 10^{-3} \cdot 10^{-4}$ cm.^{3}, we obtain as the value of K, 10^8 sec.$^{-1}$ cm.$^{-3}$. This value of K can be interpreted as indicating that the nuclei of martensite form in special locations in the solid solution.

The value of U for the transformation of austenite to martensite is small, being on the order of 1000 cal. per mole. The velocity of transformation is already very large at temperatures above −50° C. (−58° F.). While U does not depend on temperature, the value of the work of critical nucleus formation, W, increases with increasing temperature, and at the temperature T_o of phase equilibrium between austenite and martensite, W must increase without limit. Therefore, with increasing temperature the value of W must become equal to U at some point and then surpass it. The velocity of transformation in this temperature interval must decrease and become practically equal to zero at a certain distance from T_o.

However, in studying the temperature dependence of the velocity of transformation in a series of steels, only an increase in the velocity of transformation with increasing temperature was observed. All values of

$$\ln\left[\frac{1}{V_o'}\left(\frac{dV}{dt}\right)_{t=0}\right]$$

showed a straight-line relationship to 1/T, conforming with equation 1. The tapering off of the isothermal

(Continued on p. 126)

Formation of Martensite Nuclei

(Continued from p. 124)
transformation occurred more rapidly the higher the temperature, and at temperatures above −50° C. (−58° F.) the limiting amount of martensite was formed in the time necessary to reach temperature. Therefore, isothermal transformation in this region could not be observed.

Another fact was determined in studying the temperature dependence of the velocity of isothermal transformation of an iron with 23% nickel and 3.4% manganese. On continuous cooling at a velocity of 10° C. per min., transformation began at −17° C. (1° F.), which was taken as the martensite point for this alloy. However, kinetic transformation curves obtained at constant temperature showed that transformation occurs also at higher temperatures (Fig. 1). It appeared that the

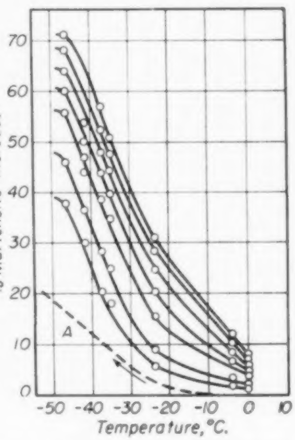
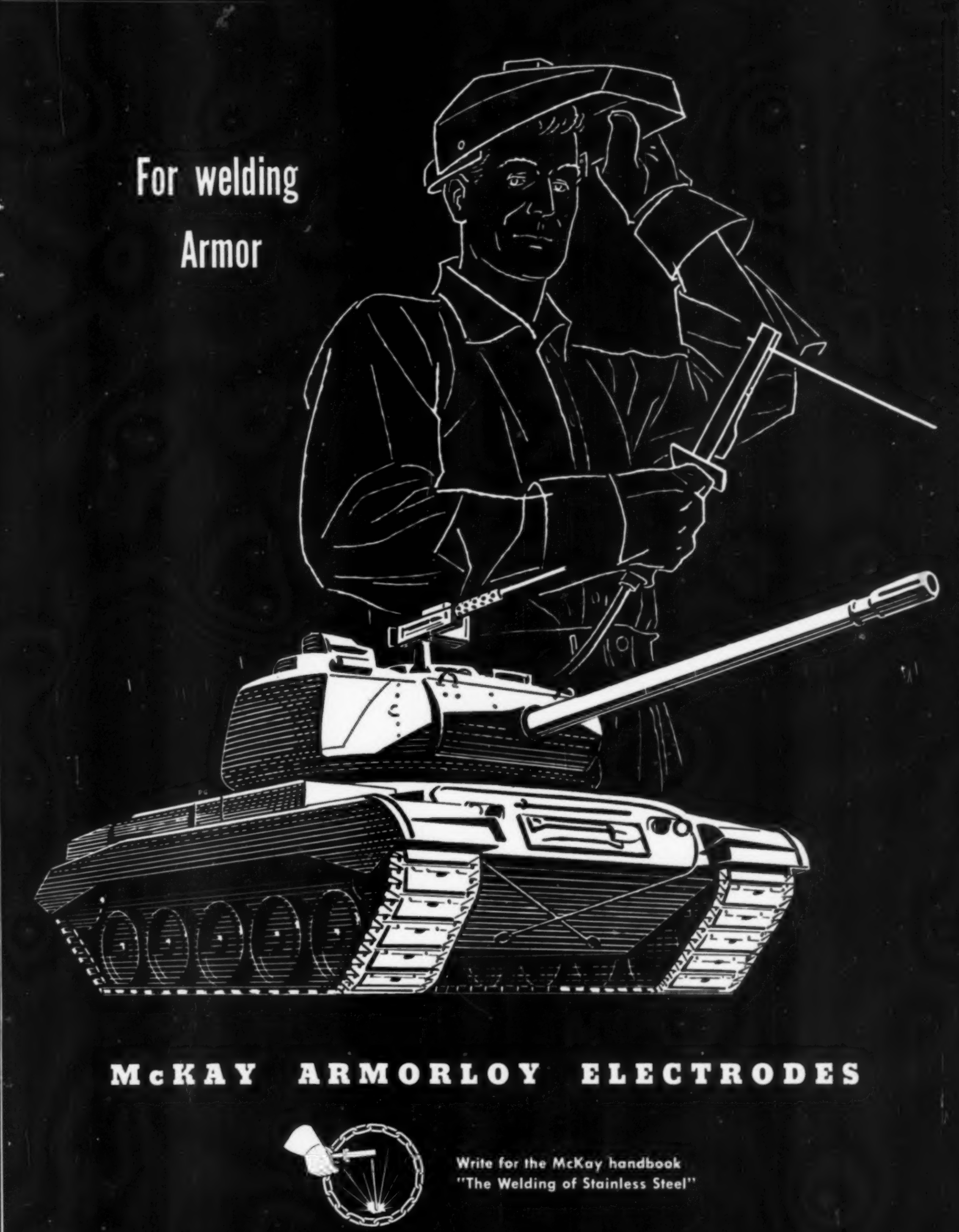


Fig. 1 — Increase in the Amount of Martensite for Various Holding Times Near the Martensite Point. Below −47° C. transformation decreased with decreasing temperature, and above this point it decreased with increasing temperature. Curves from top to bottom are, respectively, 10, 5, 2 and 1 hr., and 30, 10 and 5 min. holding times. "A" is cooling curve (10° C. per min.)

velocity of tapering off of the transformation was a maximum at −47° C. (−53° F.).

The temperature dependence of the velocity is shown in Fig. 2 in which isotherms of "relative amount" of martensite, V/V_0', are given. The curve of the change of the initial velocity of transformation with temperature (Fig. 3) has a maximum as

(Continued on p. 128)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Formation of Martensite Nuclei

(Continued from p. 126)

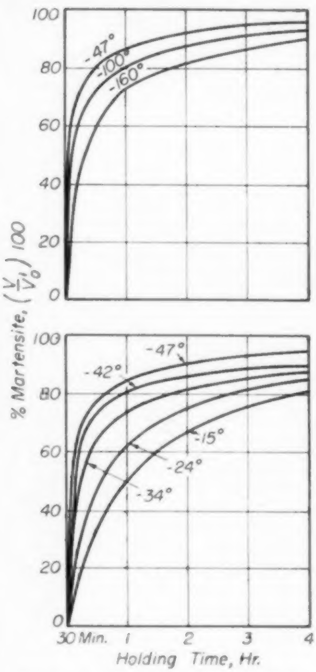

Fig. 2 — Relative Amount of Martensite as a Function of Time of Holding at Various Temperatures

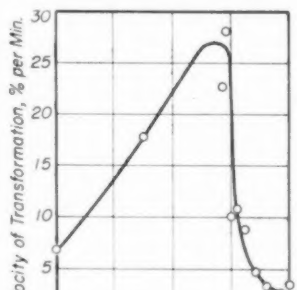

Fig. 3 — Initial Velocity of Transformation as a Function of Temperature

is usual in a crystallization process.

Figure 4 shows that at temperatures below −50° C. (−58° F.), the points fall on a straight line. In accordance with equation 3, it follows that in this temperature range

(Continued on p. 146)

METAL PROGRESS

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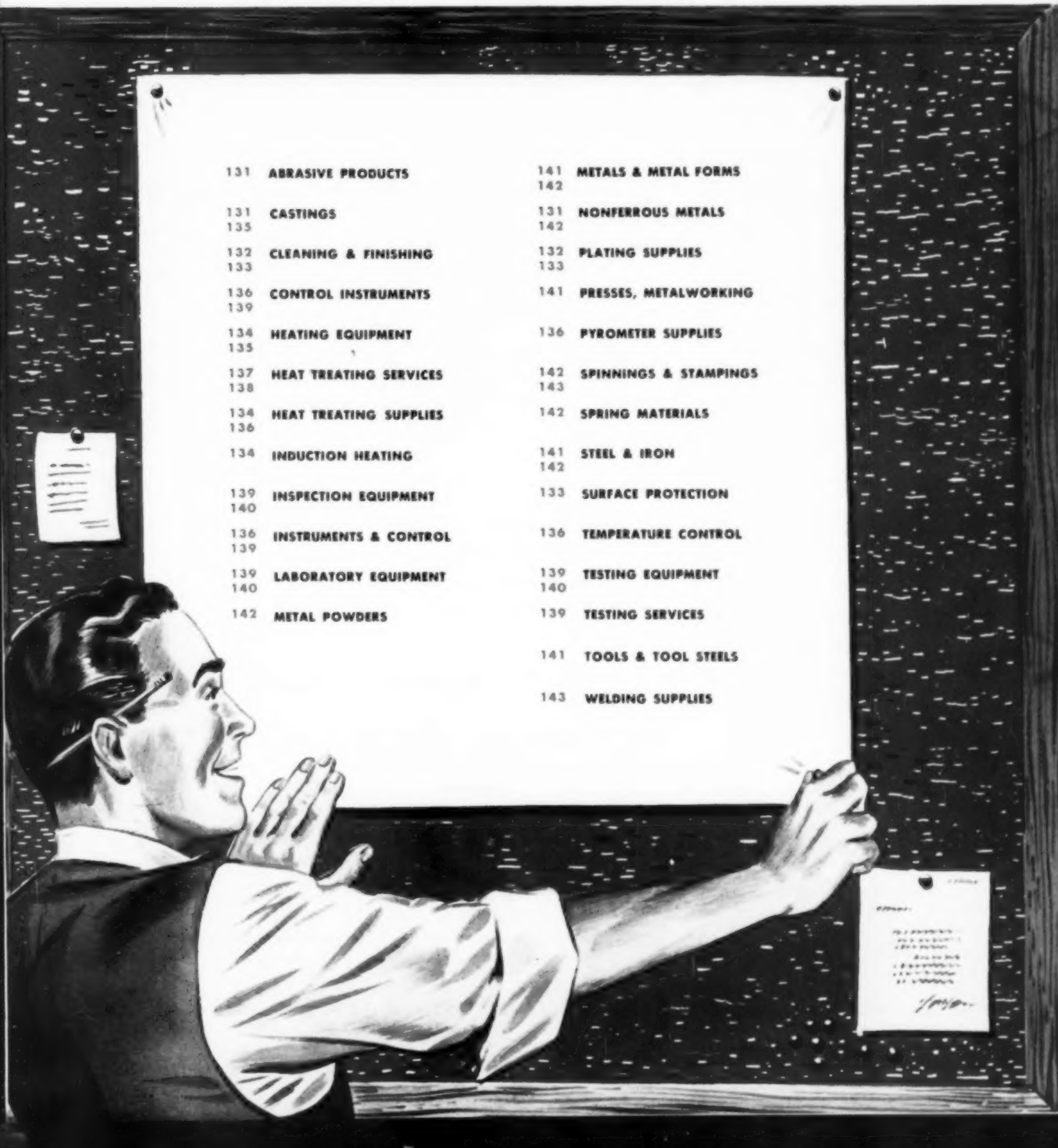

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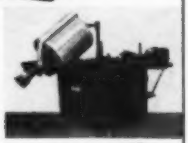

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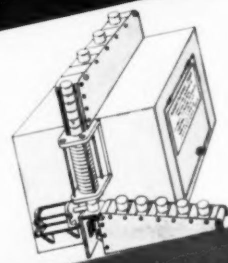

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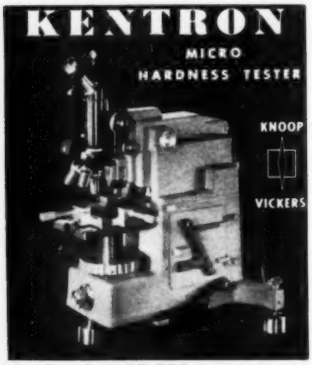

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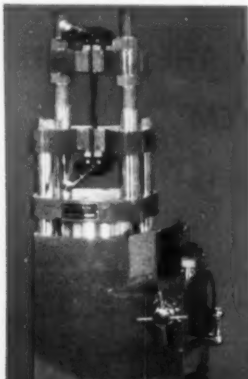

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Formation of Martensite Nuclei

(Continued from p. 128)

the work of forming a nucleus is small compared with the activation energy. The latter is equal to 600 cal. per mole. Therefore,

$$\ln \frac{1}{V_0'}\left(\frac{dV}{dt}\right)_{t=0} = \ln A - \frac{U}{RT} \cdot \frac{1}{T}$$

At temperatures above -50° C. (-58° F.) the points lie below the straight line, and they are farther from it the higher the temperature. Evidently in this temperature range the work, W, is comparable with U and must be taken into account. The above expression then becomes

$$\ln A - \frac{U}{R} \cdot \frac{1}{T} - \frac{W}{R} \cdot \frac{1}{T}$$

The amount of departure from the straight line is equal to (W/R)·(1/T), and this permits the determination of the temperature dependence of the work of nucleus formation in this range of temperature. The value of W determined in this manner was practically zero at -50° C. (-58° F.) and lower temperatures, 100 cal. per mole at -40° C. (-40° F.), 700 at -30° C. (-22° F.), and 1400 at 0° C. (32° F.).

The authors state also they have shown in previous work that, at

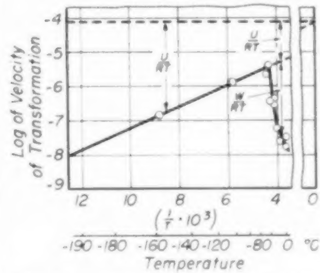


Fig. 4 — Dependence of the Logarithm of the Initial Velocity of Martensite Transformation on Temperature

sufficiently low temperatures, the velocity of transformation becomes measurable, and this velocity decreases on further reduction of the temperature. It is the belief of the authors that this investigation has shown the velocity of transformation in the neighborhood of the martensite point to be slow because of the action of the factor $e^{-W/RT}$. Since W rapidly decreases with increase in undercooling, the velocity of transformation rapidly increases with decrease of temperature in the temperature range in which $e^{-W/RT}$ is a decisive factor. A. G. Guy

British Views of U.S. Nonferrous Industry*

This is a report of a 1950 visit to this country by a productivity team representing the wrought nonferrous industry of the United Kingdom. The team worked under the aegis of E.C.A. and the Anglo-American Council on Productivity, and was one of a number of similar teams from other industries and other countries. What they have to say is of interest to any brass mill man and, in its implications, to anyone aware of the relation between production and living.

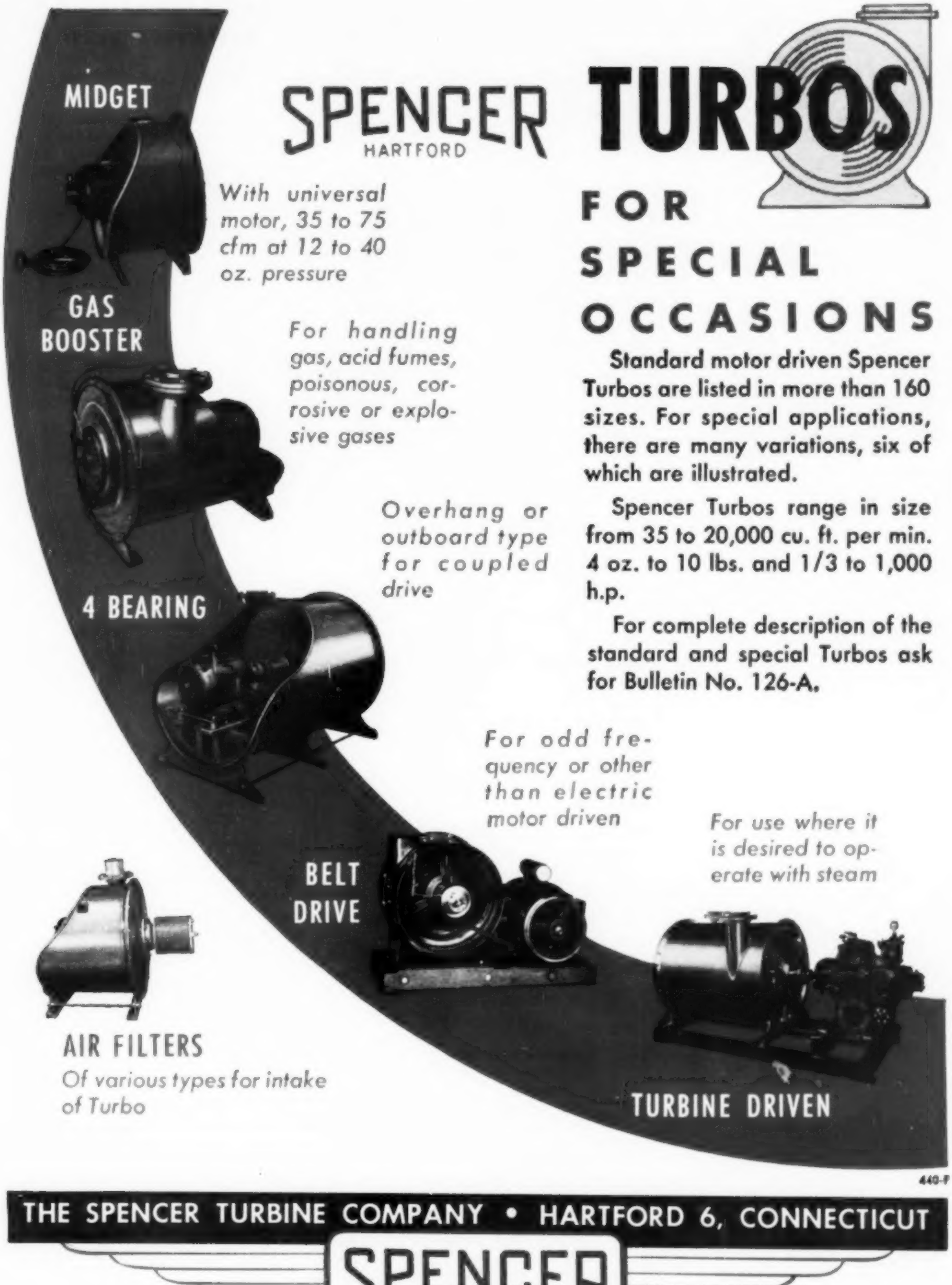
The team was composed of representatives from both management and labor, whose specific interests embraced administration, engineering, labor relations, casting, and production. They were again cross-grouped for casting, rolling, extrusion, wire, and tubes. Thus, all phases of the operational side of the industry are covered. It is a very human tendency to forget that a brass mill, or any integrated industry, consists of many parts, but this report maintains a balanced perspective without losing sight of the main theme — that the ultimate purpose of a brass mill is to produce brass and that economic necessity requires efficiency.

However, the nub of the question hinges on the degree of efficiency, which is not always so easily defined. The report is solidly based on this premise: "To study methods employed in the U.S.A. . . ."; "To exchange information with . . . opposite numbers in the U.S.A."; "To compare methods employed in the United Kingdom".

The itinerary of the team shows that it worked from the brass mills of Connecticut, across New York State to the lake cities of New York, Ohio, and eastern Michigan, returning through Washington and Philadelphia to headquarters in New York City. Observations are recorded in detail, with sketches. One is impressed with the thoroughness and competence of this work. No important feature of mill equipment or arrangement seems to have been overlooked: the examination is thorough and critical, always with an eye to things that are in

(Continued on p. 150)

*Abstract of "Productivity Report on the Wrought Nonferrous Metals Industry by the British Nonferrous Metals Productivity Team", obtainable from Anglo-American Council on Productivity, 2 Park Ave., New York City. (75¢.)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British Views of U. S. Nonferrous Industry

(Continued from p. 148)

process of development or only newly established. These specific notes, grouped by general brass mill divisions, such as rolling, tubes, wire and others, are, for each division, followed by a summary and over-all discussion, and finally by specific recommendations to British brass mills. The over-all discussion is keen and searching, and scrupulously factual. It is based on what had actually been seen and while comparison with British practice is not overstressed, it is not avoided. The recommendations are for British consumption, hence they are confined to points worthy of emulation. The scope of these may be gathered from the section entitled "General Recommendations":

"1. That British industry should set up a permanent organization for sectional Productivity Teams to survey periodically the British nonferrous metals industry, covering the main processes: melting and casting, rolling, extrusion, wire-drawing and tube-drawing.

"2. That interchange of visits with our opposite numbers in the U.S. should be encouraged either by the industry or by individual companies.

"3. That management should give earnest attention to process planning, without which satisfactory improvement in productivity cannot be achieved or maintained.

"4. That development engineering should be intensified.

"5. That manufacturers, both large and small, should apply the principles of work study, if they have not already done so. Full co-operation with the development engineer is essential. In particular, study shoud be made of the operation of every machine to see that it is producing at the highest possible efficiency rate. This is largely dependent upon the transfer of material from one operation to the next, the suitability of the material to enter the machine immediately and the siting of the machine.

"6. That there should be a more intensive effort, in which trade unions should join, to make it more universally understood that higher productivity means a higher standard of living.

"7. That every effort should be made to increase the use of materials of standard dimensions and standard compositions, and that we

(Continued on p. 152)

British Views of U. S. Nonferrous Industry

(Continued from p. 150)

should copy the American practice of heavily penalizing nonstandard material and small lots."

These are heartening words, for the seeds of sophistry and laxity are everywhere, but the hard fact remains that what we have depends, in the end, on what we can produce. While the British Team has been studying U.S. methods they have, more broadly, been studying a problem which is ours as well as theirs. There is no ground anywhere for complacence.

D. R. Hull

Openhearth Charge Ores*

The ideal openhearth charge oxide would probably consist of hard, dense lumps of hematite ore, free of fines, with a size distribution ranging from 8 to 1 in. Acid oxides such as silica and alumina are undesirable; on the other hand, moderate amounts of basic oxides such as lime, magnesia, and manganese oxide have no undesirable effect. Phosphorus can be eliminated; however, the presence of any sulphur is undesirable.

A moderate amount of natural moisture can be tolerated since it can readily be driven off at temperatures attained during the meltdown period, provided the size of the ore pile is not so great as to prevent heating.

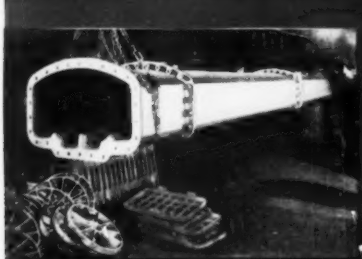
The furnace operator is concerned with the various chemical reactions that occur in the furnace when hot metal and charge ore react, only to the extent of their effect on subsequent melting and refining operations. From his viewpoint, the ideal charge ore would react rapidly with the hot metal, with a controlled and uniform action. Silicon, manganese and phosphorus in the hot metal would oxidize rapidly to form a hot fluid slag that would run freely out of the flush hole. There would be no tendency for ore or metal to be carried out of the furnace with the flush slag. A maximum amount of flush slag would be removed in a short time. The rate of heat trans-

(Continued on p. 154)

*Extracts from paper of this title read before May 1951 meeting of American Iron and Steel Institute by J. J. Golden and H. E. Warren, Jr.

Retort weighing 2,000 pounds is machined in a D-H machine shop. Retorts up to 5,000 pounds can be handled here.

D-H
FURNACE PARTS AND FIXTURES
mean
LOWER HEAT-HOUR COSTS



Muffle weighing 6,500 lbs. being assembled in a D-H foundry. One section Nichrome, remainder Chromax. (Note trays and other fixtures nearby.)

Spectrograph equipment at Driver-Harris supplies one of the most efficient means for precise metallurgical control.

Low heat-hour costs are "manufactured" in the form of durable equipment that can deliver peak performance economically throughout a long life of trouble free operation.

To manufacture low-heat hour costs requires exceptional facilities: A reservoir of accumulated heat-treating experience, a profound knowledge of metallurgy, a corps of expert technicians, and ready availability of all necessary means for producing furnace parts and fixtures—so that checks and controls can be easily and efficiently applied at all stages of manufacture.

At Driver-Harris, we have all of these. We have amassed over 40 years of practical foundry experience. We have developed, with exclusive techniques, the highest-grade nickel-chromium alloys—such as Nichrome* and Chromax*—that give top-level performance and stay on the job despite high heat, punishing cycles and fast quenching. Our engineering and designing divisions, furnaces, pattern shops, foundries, rolling mills, welding and machine shops provide all the facilities for manufacturing furnace parts and fixtures of all types, utilizing castings, sheet, bars, wire, or wire mesh.

Size is no object. Whether it be baskets weighing a few pounds each, or retorts weighing several thousand pounds apiece, we are equipped to supply units "tailored for the job."

Under present conditions, strategic metals and the alloys made from them are inevitably on strict allocation. However, we shall be glad to make recommendations based on your specific needs, and serve you to the best of our ability.

*T.M. Reg. U. S. Pat. Off.

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MAKERS OF WORLD-FAMOUS NICHROME AND OVER 80 ALLOYS FOR THE ELECTRICAL, ELECTRONIC AND HEAT-TREATING FIELDS

Openhearth Charge Ores

(Continued from p. 152)

fer through the thin remaining slag would be rapid, enabling subsequent melting and refining reactions to proceed without delay.

The general procedure for comparing operating performances was to charge one half of the furnaces in the test shop with one grade of ore and the other half with a second grade for one half of the month, and then the furnaces were reversed.

Brazilian ore more closely approaches the ideal charge ore than any other ore in use in this country today. The nodules used in this test were probably typical of the product in general use in the industry, the physical characteristics being more of the nature of a roasted ore than a true nodule. In tons per melting hour, nodules ranked intermediate between Brazilian and Swedish Kiruna ores. It is hoped that ultimately a hard, dense nodule, free from objectionable fines, will be produced.

In each of the tests, production performance with Swedish Kiruna was inferior to that of the comparison ore. The authors believe that magnetite ores are, in general, inferior to hematite ores as to their effect on heat time, bottom delays and sulphur elimination.

Some plants in the industry are using magnetite ores, particularly Swedish Kiruna, with excellent results. The authors' experience with magnetite ores has largely been confined to large furnaces with a relatively deep bath. Other plants with smaller furnaces and shallower baths are able to charge less ore and, because of the shallow bath, the bottom heats up faster and the reaction proceeds without delay.

Within the last few years, a product known as "blocked iron" has come into limited use. This material is produced by combining fine ore with a binder and molding the mixture into six to eight-in. cylinders. The blocked product is remarkably stable and offers another means of using fine ores.

In one test, blocked iron was superior to charge ore, both from the standpoint of production rates and ore requirements.

Conclusions — A direct comparison cannot readily be made between the various ores because of the changes in other operating conditions which took place from test to test. *(Continued on p. 156)*

Openhearth Charge Ores

(Continued from p. 154)

It has been found that an ore, which works satisfactorily at a given pig percentage in a furnace of, say, 120 tons, may be entirely unsatisfactory in a furnace of 225 tons, probably because the relative time required to heat the center of a pile in the large furnace is more than twice the time required for the smaller furnace using half the total amount of ore.

Fine ore can be improved by mixing it with more lumpy ores, solely because the more open pile allows the hot metal to mix more readily with the ore earlier in the heat time and also allows combined moisture to escape more easily, which in turn helps to eliminate violent blows in the furnace.

The relative depths of bath, firing rates, temperature of furnace at charge time, would each have its different effect on the results obtained from the use of a given ore.

At the present rate of ingot production, approximately 10 million net tons of charge ore will be required annually. Too small a percentage of this ore is available in the higher quality grades, including the better grades of imported ores.

Notch Toughness of Low-Alloy Steels*

A STUDY of more than 450 specimens of low-alloy steels emphasizes the difference between the notch toughness and ductility as measured by the tension test. Using 25 low-alloy steels of standard S.A.E. grades and a few non-standard steels having carbon contents from 0.10 to 0.65%, fully martensitic structures were produced with oil or brine quenching. Hardnesses for the as-quenched 0.10 to 0.65% carbon steels were Rockwell C-39 to C-58. Tempering in the range of 300 to 1150° F. produced many high and low carbon specimens of approximately equal hardness. Notched toughness (Charpy keyhole) varied considerably for the equal hardness specimens. At a hardness of Rockwell

Continued on p. 158)

*Abstract of "Notch Toughness of Fully Hardened and Tempered Low-Alloy Steel", by R. L. Rickett and J. M. Hodge, presented at the Annual Meeting of the American Society for Testing Materials, June 18-22, 1951.

Notch Toughness

(Continued from p. 156)

C-50, notched toughness varied from 3 to 27 ft-lb.; Rockwell C-40, notched toughness ranged from 12 to 39 ft-lb. The authors state, "This spread is contrary to the general observation that the ordinary mechanical properties of tempered martensite, within certain limits of hardness or tensile strength, are relatively constant regardless of the type of steel."

A statistical evaluation of the data obtained by the authors, together with other data available to them, discloses a very marked relationship of notched toughness with carbon content. In fully quenched and tempered martensitic structures of the same hardness, low carbon steels possess higher notched toughness than high carbon steels.

The authors' statistically derived "averages" indicate that at a hardness of Rockwell C-40, steels in the 0.09 to 0.19 carbon range have a notched toughness of 30 ft-lb., as do the steels in the 0.20 to 0.29 carbon range. However, steels of 0.30 to 0.39% carbon have a notched toughness of 26 ft-lb., for the 0.40 to 0.49% carbon steels it is 23 ft-lb., and for the steels in the 0.50 to 0.64% carbon range it is 12 ft-lb.

The extensive statistical treatment of their data has permitted the authors to derive the following equation relating Charpy keyhole notched toughness with hardness and carbon content:

$$\text{Charpy value (ft-lb.)} = 79.0 - 1.08 \text{ (Rockwell C hardness)} - 29 \text{ (\% C)}$$

This equation can be useful to other investigators working with fully quenched and tempered martensitic structures. The assumed linear relationship between notched toughness and carbon content used in the multiple regression statistical treatment of the data accounts for "about 85%" of the total variability of the data.

The data are statistically consistent when replotted on the basis of tempering temperature rather than carbon content. For equal hardness, the higher carbon steels would be expected to require higher tempering temperatures than the lower carbon steels. A statistical treatment of the data relating notched toughness with tempering temperature rather than with carbon content gives the same result for equal hardness; high tempering temperature gives lower notched

(Continued on p. 160)

Notch Toughness

(Continued from p. 158)

toughness than low tempering temperature.

Using only a few of the steels of the previous study, the authors made detailed density measurements and impact tests of specimens quenched and tempered and of specimens that were refrigerated at $-320°$ F. to transform any austenite retained between quenching and tempering. They conclude that while some retained austenite was present in some specimens, there was no effect of this condition on notched toughness.

The notched toughness of fully quenched and tempered low carbon alloy steel at room temperature is higher than that of similarly treated higher carbon alloy steel at the same hardness level. This fact can be of considerable benefit in industrial applications when the material can be fully quenched without cracking to produce the hardness-strength levels for which the higher carbon steels are usually selected.

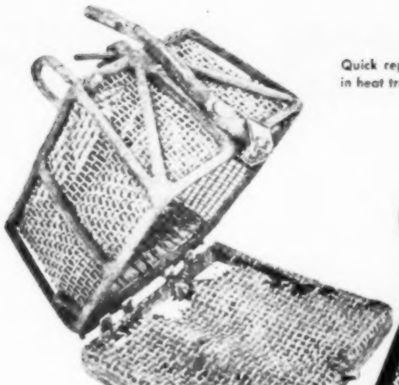
LEO SHAPIRO

Bauxite Pig Iron*

"BAUXITE PIG IRON", the pig iron produced from calcium-aluminate slag, is low in sulphur (0.049 to 0.57%) and high in carbon (0.5 to 1.9%); therefore, its suitability as a raw material for foundries was investigated. Melting experiments were conducted in a 24-in. diameter cupola furnace with two types of bauxite pig iron to learn whether this iron can replace coke-produced pig iron in gray cast iron, to establish the quantity necessary to obtain the best results, and to observe the effect on the structure and strength of the product.

The authors report that the results of the experiments proved the suitability of bauxite pig iron for the manufacture of gray castings. If its composition is satisfactory, it may be utilized for malleable castings. However, bauxite pig iron has the disadvantage that its composition is not homogeneous, especially its silicon content which fluctuates between broad limits. Homogeneity would have to be ensured for its use in large-scale production.

*Abstract of "Possibilities of Utilizing the Pig Iron Produced From Calcium-Aluminate Slag of Foundries", by N. Hajto and F. Varga, *Journal of Mining and Metallurgy* (Hungarian), Vol. 4 (82), November 1949, p. 483-489.



Quick repairs give extra long life to this Inconel basket used in heat treating small steel parts in a 1600° F. molten salt bath.

The before and after story of

an Inconel basket in 1600° F. molten salt

Salt bath dump bottom baskets for case hardening parts have to stand extra tough service.

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Time after time – loaded with 80 to 100 pounds of small steel parts – it has taken half-hour 1600° F. baths in molten salts.

For 26 months the basket took such abuse. Then it was returned to Rolock, Inc. to be repaired. Then it went back to work again and gave 13 months more service.

Now it has been repaired again and is back on the job for the *third* time.

Just take a look at the photo on the left. That's how it looked when sent back for repairs the second time. Now take a look at the one on the right. Yes, it's the same basket after being repaired. Now it's back in service adding more time to an already outstanding service life of 39 months!

The fabricator, Rolock, Inc. of Fairfield, Conn. chose Inconel for the basket because of its strength and workability and because of its good resistance to high temperature oxidation and corrosion.

Right now, of course, Inconel is on extended delivery because so much is needed for defense. Therefore, it will pay you to place your orders for it well in advance of the time you expect to use it. Consult your supplier about availabilities. And remember, Inco's Technical Service Section is always ready to assist you with your heat treating problems. Write them today.

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New Equipment for Fatigue Tests

Technical News Bulletin of the National Bureau of Standards (July 1951, p. 103) describes three devices recently installed by staff-members John A. Bennett and James L. Baker on fatigue testing equipment at the Bureau. One stops the rotating beam machine when a surface crack appears, equal in length to 5 to 10% of the circumference of the specimen. It is based on the principle that such a specimen will bend a little more when the cracked element is at maximum tension than when the specimen rotates away from that position. In such circumstances the bearing boxes supporting the loads will vibrate, and the stopping devices operate when such vibration reaches a reproducible minimum.

For this, the end of a horizontal lever fixed to one of the bearing boxes carries an adjusting screw that bears on the actuating leaf of a microswitch. After the machine has run long enough to reach temperature equilibrium, the adjusting screw is advanced until a very small change in the position of the lever will trip the switch and shut off the machine. This device is run in parallel with a vibration-responsive stopping device; the latter is fastened rigidly to one of the bearing boxes, and consists of a steel ball poised on a three-pronged pedestal. Vibration resulting from an incipient crack shakes the ball from its perch; in falling, it closes an electrical circuit that shuts off the machine. Sensitivity of this device may be adjusted by varying the distances of the pedestal prongs from each other. Sometimes the microswitch will respond first, sometimes the falling ball.

Thin Sheet Specimens, tested in reversed bending, require quite large deflections to give high surface stresses, and this limits the ordinary cantilever tests to gages thicker than 0.015 in. Bennett and Baker test thinner sheets by deflecting the specimens as short columns; bent columns give the necessary radii of curvature to induce damaging stresses.

The device consists of a fixed anvil capable of gripping the bottom ends of a row of seven specimens, each 1 in. high by ½ in. wide. The top of these specimens is held in a similar arm-like grip, one end of which is pivoted and the other end connected to a crank.

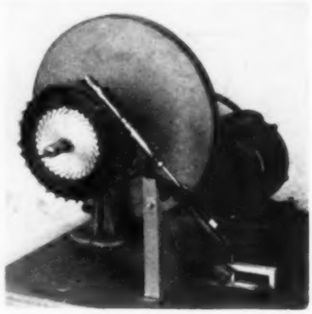
(Continued on p. 164)

New Equipment for Fatigue Tests

(Continued from p. 162)
Operation of the crank lowers and raises the arm's end; at the top of its travel the arm and anvil are parallel and the samples unstressed; at the bottom of its travel the specimen nearest the crank is stressed most highly and will break first, the one nearest the pivot is stressed least and will break last.

An automatic stopping device used with the machine takes advantage of the fact that after a crack forms, the specimen no longer deflects in a smooth curve. An adjustable contact assembly is clamped to the lower arm or anvil of the machine and is adjusted so the intact specimen nearest the crank just fails to touch the contact disk at its maximum deflection. A small crack causes the specimen to deflect more than this, and it makes electrical contact with the disk, thus stopping the machine by suitable relays. After this specimen has been removed and the number of cycles recorded, the contact assembly is moved to the next specimen and the machine restarted. Since as many as seven specimens can be tested at once, the fatigue properties of a material can be determined over a wide range of maximum strain values in a short time.

Specimen Polisher — The accompanying halftone illustrates a device for polishing fatigue specimens.



The abrasive belt is held to correct contour radius (usually 4 in.) by metal spring leaves; the specimen is rotated slowly (ratio 1 to 100) under light, controlled pressure, and at the same time moves gradually across the abrasive belt. Thus fresh abrasive is continually brought into use, resulting in a cutting action rather than an undesirable rubbing action.

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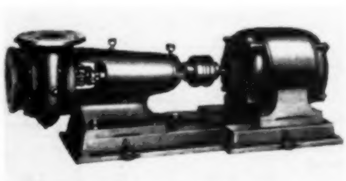
Properly designed to induce maximum turbulence in the quench oil. B & G quench tanks are available in standard models or can be built to meet any specific quenching requirements.



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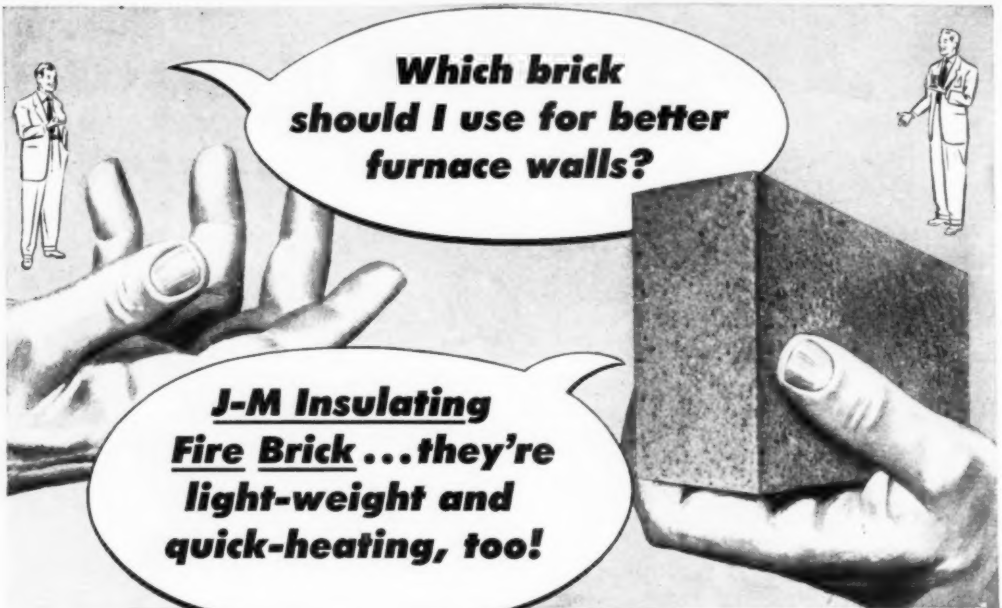

6 types . . . for savings in services up to 3000F

Because of their quick-heating and low-heat transfer characteristics, Johns-Manville Insulating Fire Brick are efficient fuel-savers for use at operating temperatures up to a full 3000F on the insulation.

Each type of J-M Insulating Fire Brick has the correct balance of thermal and physical properties that assures maximum economies within a specific temperature range. All types are *quick-heating* . . . operating temperatures are reached in a short time, thereby saving fuel.

Identical materials can also be obtained in large size units known as Johns-Manville Insulating Fireblok. Fireblok have the same properties as the brick, but are made in extra large sizes for added construction economies. The large units can be installed faster . . . require fewer joints and less bonding mortar. During rebuilding or repair, furnace down-time is appreciably shortened with Fireblok construction.

A Johns-Manville insulation expert will gladly explain the advantages and economies of using J-M Insulating Fire Brick and Fireblok for refractory linings or as back-up insulation behind other refractory protection. Write to Johns-Manville, Box 290, New York 16, N. Y. In Canada, write 199 Bay St., Toronto 1, Ontario.

Properties	Types of Insulating Fire Brick and Fireblok					
	JM-3000	JM-28	JM-26	JM-23	JM-20	JM-1620
Temperature limit	†3000F	†2800F	†2600F	†2300F	†2000F	‡2000F †1600F
Density, lb per cu ft	63–67	58	48	42	35	29
Transverse strength, psi	200	120	125	120	80	60
Cold crushing strength, psi	40	150	190	170	115	70
Linear shrinkage, percent	*0.8 at 3000F	4.0 at 2800F	1.0 at 2600F	0.3 at 2300F	0.0 at 2000F	0.0 at 2000F
Reversible thermal expansion, percent	0.5–0.6 at 2000F	0.5–0.6 at 2000F	0.5–0.6 at 2000F	0.5–0.6 at 2000F	0.5–0.6 at 2000F	0.5–0.6 at 2000F
Conductivity (Btu in. per sq ft per F per hr at following mean temperatures)						
500F	3.10	2.00	1.92	1.51	0.97	0.77
1000F	3.20	2.50	2.22	1.91	1.22	1.02
1500F	3.35	3.00	2.52	2.31	1.47	1.27
2000F	3.60	3.50	2.82	2.70	1.72	....

*24-hr Simulative Service Panel Test; all others 24 hr soaking period. †Back-up or exposed. ‡Back-up only.

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IN HIGH VACUUM a film of aluminum .000005" thick is about to be deposited on a load of transparent polystyrene plaques.

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DPi makes the most efficient vacuum metallization equipment you can buy and stands ready to work with you in selecting your lacquers and lacquering equipment. We suggest you write for further information to ***Distillation Products Industries,*** Vacuum Equipment Department, 753 Ridge Road West, Rochester 3, N. Y. (Division of Eastman Kodak Company).

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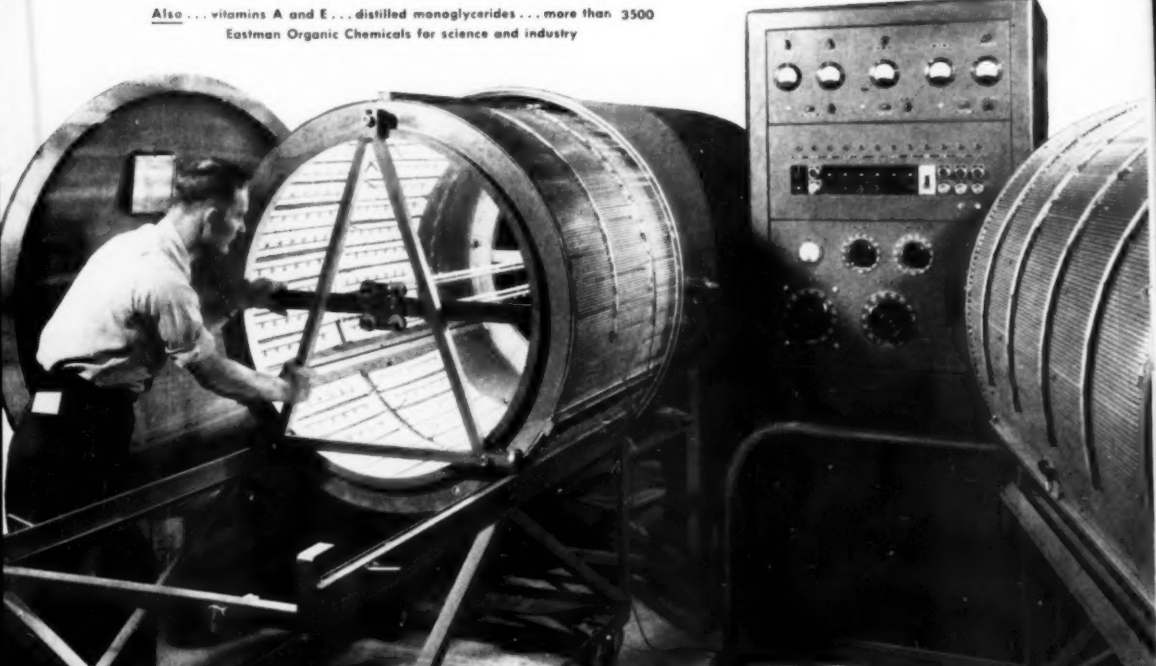

Republic Carbon-corrected Cold Drawn Alloy Steels make the square heads of these set-screws tough right out to the corners to withstand wear longer without rounding off.

MAGNESIUM

and the problem of

COST

in your product

THE cost of any metal extends much further than just the cost of raw ingots. This is particularly true of magnesium, a metal that offers many economies from ingot to your finished product.

At the ingot stage, magnesium has an outstanding record of price stability. By its very nature . . . electrochemically extracted from unlimited sea waters at our own shores . . . that stability is inherent.

Then there is the cost of metal fabrication, a cost largely dependent upon fabricating knowledge and facilities. Perhaps no other metal has advanced so rapidly in fabricating techniques in the past ten years. Today, magnesium is produced in all common forms such as extrusions, sheet, plate or castings at prices generally competitive with other metals.

Within your own plant, magnesium offers many economies. It is one of the most machinable of all metals. It has excellent hot drawing qualities, permitting deeper draws than any other metal. And throughout your manufacturing and distributing processes, magnesium's light weight cuts the costs of transportation and handling.

But above all, magnesium cuts the competitive penalty of weight at the point of sale. Wherever a product is made to be moved, either by human or mechanical means, magnesium offers a real sales advantage, for it is the world's lightest structural metal . . . one-third lighter than the next lightest metal.

For your "Tomorrow's" Product . . .

Today, magnesium is a tremendously important part of our defense effort, and like many other metals, is required in great quantities by the government. But in planning "Tomorrow's" production, remember this fact: the seas, at our own shores can provide 100 million tons of magnesium per year for 1,000,000 years without significantly reducing the supply!

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MAGNESIUM

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They are designed primarily to save nickel and molybdenum that are urgently needed for certain defense applications.

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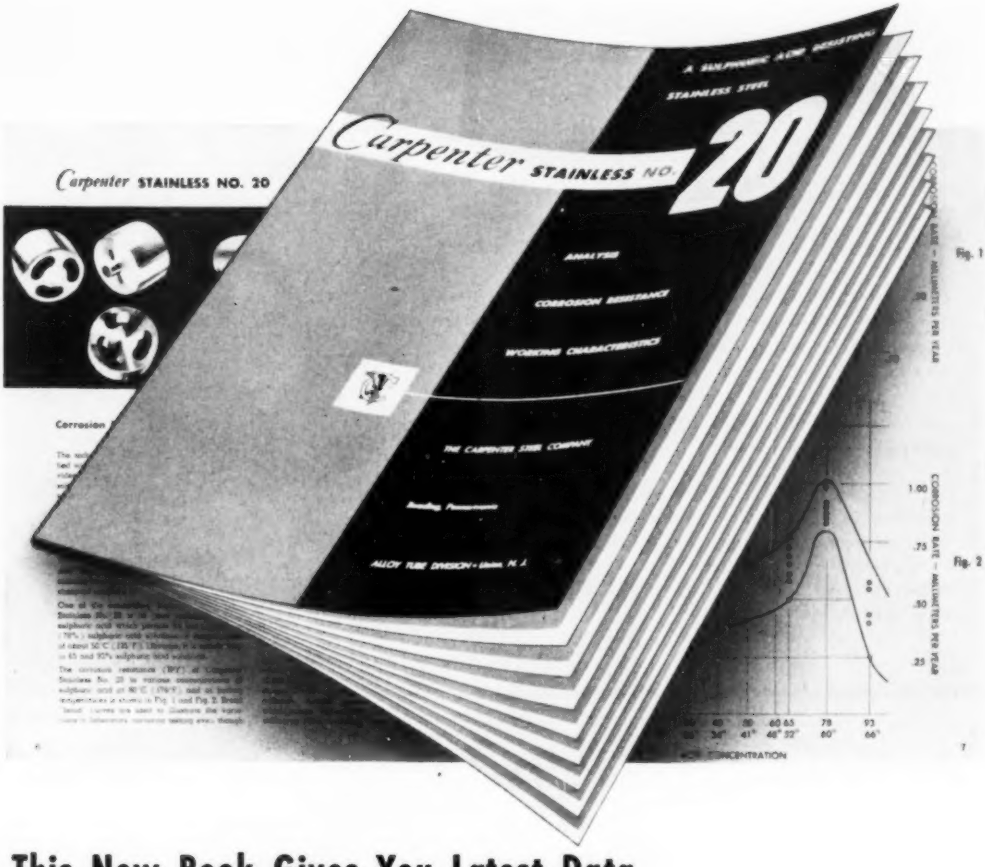

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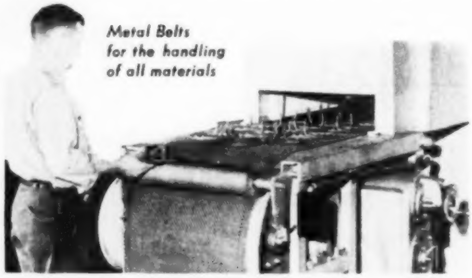

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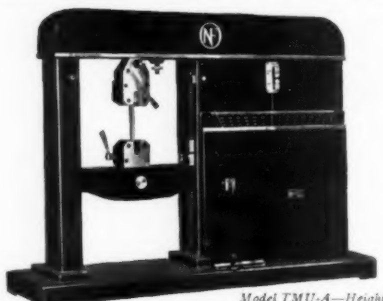

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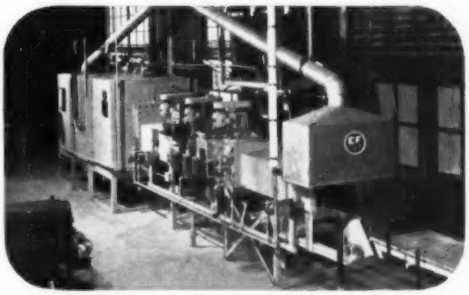

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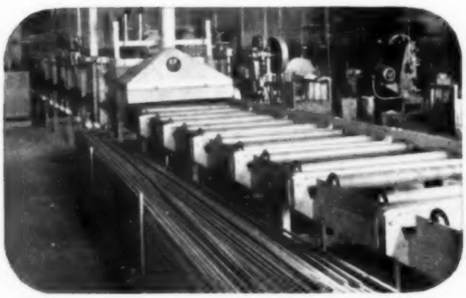

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